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Welcome to the Northeast Decision Sciences Institute Conference  
Springfield, Massachusetts  
March 22 – 25, 2017

Greetings to all:

We would like to take this opportunity and thank you for participating in the Northeast Decision Sciences Institute Conference (NEDSI) 2017, Springfield, Massachusetts.

As you know, our colleague and friend, Dr. Richard Briotta from Bay Path University, was to be the NEDSI Program Chair for 2017. Unfortunately, Dick passed away last year. We are dedicating the conference to his memory. We have also established an award under his name for the best paper in the field of Knowledge Management and Strategy.

We are delighted to report that the conference includes 176 accepted submissions by 302 authors from 127 different universities and organizations and 16 countries. The conference has 30 tracks and 59 track chairs from 9 countries.

With the diversity of countries, universities, organizations and academic disciplines represented in this conference, we will have a fantastic opportunity to share our knowledge.

We hope this conference will encourage you to participate in future Northeast Decision Institute conferences.

I look forward to meeting you and wish you a great time in Springfield.

Best, Minoo

Minoo Tehrani, Ph.D.  
Program Chair, NEDSI 2017 Conference  
NEDSI Immediate Past President
Welcome to NEDSI

For those of you who are reading about us for the first time, let us explain a little about our group. We are one of several regions that comprise our national professional society, the Decision Sciences Institute (DSI). Our region encompasses the Northeastern United States.

Northeast Decision Sciences Institute (NEDSI) holds an annual regional meeting each spring that features presentations of original research papers, Ph.D. and new faculty development seminars, panels, workshops, and other interesting innovations in the fields of business. Every year, we have several exhibitors that join our conference.

Awards for "Best Paper" in different categories are given each year in addition to the awards for the best students’ presentations in three different categories, undergraduate, master’s, and Ph.D. students’ categories.

Our national organization, the Decision Sciences Institute, holds annual meetings and publishes the Decision Sciences journal, Decision Sciences Journal of Innovative Education, and Decision Line. Please check the site at dsi.org.
NEDSI 2017 Conference Sponsors & Exhibitors

We wish to thank the sponsors of this conference:

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Corporate Social Responsibility
Doug Hales………………………………………………………..University of Rhode Island
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e-Commerce
Sung J. Shim……………………………………………………………Seton Hall University
Suhong Li…………………………………………………………………Bryant University

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Mahour Parast ……………………………………………………. NC A&T State University
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Health Care Management
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Neset Hikmet……………………………………………………………University of South Carolina
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Brendan D. Bannister .......................................................... Northeastern University

**Innovative Education**
Susan Bosco .......................................................... Roger Williams University
John Weber .......................................................... DeVry University

**Information Technology & Security**
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Rhoda C. Joseph .......................................................... Penn State University-Harrisburg

**International Business**
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Gayatree Siddhanta .......................................................... Linfield College

**Knowledge Management**
Jann Hidajat .......................................................... Bandung Institute of Technology
Hayward Andres .......................................................... North Carolina A & T State University

**MS/OR: Techniques, Models & Applications**
Irem Ozkarahan .......................................................... Pace University
Manouch Tabatabaei .......................................................... Georgia Southern University

**Manufacturing Management**
Farbod Farhadi .......................................................... Roger Williams University
Jiahua Weng .......................................................... Waseda University

**Marketing Theory & Practice**
Kathy Micken .......................................................... Roger Williams University
Gilles Nakhle .......................................................... INSEEC Business School

**Negotiation**
Elizabeth Volpe .......................................................... Roger Williams University
Guy Deloffre .......................................................... ICN Business School

**New Product Development & Project Management**
Matthew Liberatore .......................................................... Villanova School of Business
Dinesh Pai .......................................................... Penn State University- Harrisburg

**Organization Behavior/Organization Theory**
Deseré Kokt .......................................................... Central University of Technology
Alexander Knights .......................................................... Roger Williams University
NEDSI 2017 Conference Track Chairs (cont’d)

Quality/Productivity
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Artur Swierczek ............................................................. University of Economics-Katowice

Service Management
Hossein Safizadeh .......................................................... Boston College
Erhan Mergen ............................................................... Rochester Institute of Technology

Social Media
Sharmin Attaran ............................................................. Bryant University
Kathleen Ferris-Costa ......................................................... Bridgewater State University

Sport & Entertainment Management
Xiangrong Liu ............................................................... Bridgewater State University

Statistics & Decision Analysis
Reza Noubary ............................................................... Bloomsburg University
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Strategy
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Yu Cui ................................................................. Otemon Gakuin University

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Bilge Çelik ................................................................. Roger Williams University
Carolan McLarney ........................................................ Dalhousie University

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Attaran, Sharmin ............................................................ Bryant University
Bannister, Brendan D ......................................................... Northeastern University
Bosco, Susan M .............................................................. Roger Williams University
Cui, Yu ................................................................. Otemon Gakuin University
Farhadi, Farbod .............................................................. Roger Williams University
Ferris-Costa, Kathleen ....................................................... Bridgewater State University
Field, Joy ................................................................. Boston College
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NEDSI 2017 Conference Best Paper Awards

Best Paper Award in Contribution to Theory
The Dynamics of Punishment and Trust
Long Wang, City University of Hong Kong

Richard Briotta Best Paper Award in Knowledge Management/Strategy
The Social Dimension of Knowledge Management: A Qualitative Analysis of Multiple Cases of Social-Media-Based Knowledge Sharing
Shouhong Wang, University of Massachusetts Dartmouth
Hai Wang, Saint Mary's University

David M. Levine Best Paper Award in Innovative Education
Active Learning: Enhancing the Outcomes of Virtual Pedagogies
Peter Stonebraker, Loyola University Chicago
&
Active Teaching as a Moderator of Course Difficulty
Hayward Andres - North Carolina A&T State University

Best Paper Award in Application of Theory
An Empirical Investigation of the Impact of Cross-Border Mergers and Acquisitions on Supply Chain
Fang Chen, University of New Haven
Suhong Li, Bryant University
Jack Trifts, Bryant University
NEDSI 2017 Conference Best Student Presentation Award Winners

Presentation Award Winners

Ph.D. Student Winners


Pritha Dutta, University of Massachusetts, Amherst
Faculty Supervisor: Anna Nagurney, University of Massachusetts, Amherst

#2 (tie). Managing Cybersecurity Investment under Mutual Information Sharing Environment

Yueran Zhuo, University of Massachusetts, Amherst
Faculty Supervisor: Senay Solak, University of Massachusetts, Amherst

#2 (tie). Supplier Learning in Supply Chain Competition

Mohsen Ahmadian, University of Massachusetts, Boston
Faculty Supervisors: Roger Blake, University of Massachusetts, Boston
        Ehsan Elahi, University of Massachusetts, Boston
NEDSI 2017 Conference Best Student Presentation Award Winners (cont’d)

Presentation Award Winners (cont’d)

Undergraduate Student Winners

#1. Multinational Corporations: The Case of Brazil

Amanda Young, Roger Williams University
Emily Blackburn, Roger Williams University
Faculty Supervisor: Minoo Tehrani, Roger Williams University

#2 (tie). Sustainability & Corporate Social Responsibility: The Case of Starbucks Corporation

Francesca Montemarano, Roger Williams University
Jillian Katz, Roger Williams University
Faculty Supervisor: Minoo Tehrani, Roger Williams University

#2 (tie). Green Cities: US-Swiss Partnership

Alison Page, Roger Williams University
Meredith Bryden, Roger Williams University
Faculty Supervisor: Minoo Tehrani, Roger Williams University

3. University Naming Rights: The Impact of Branding on Student Retention

Daniel Martel, Southern New Hampshire University
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¹. Manisa Celal Bayar University, Department of Industrial Engineering, 2. Pace University, Lubin School Of Business
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1. Chelyabinsk State University, 2. Worcester Polytechnic Institute

Enhancing Students’ Employability & Cross-cultural Understanding through Storytelling
Mrs. Patricia TEHAMI¹
1. EM Strasbourg Business School - University of Strasbourg

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Dr. Elizabeth Elam¹, Dr. Jonathan Beagle¹
1. Western New England University

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1. Worcester Polytechnic Institute

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1. University of Rhode Island

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1. Bay Path University

Negotiation: Gender Impact
Ms. Quinn Orcutt¹
1. Bay Path University

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1. DeVry University

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Dr. Elizabeth Volpe¹
1. Roger Williams University

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Dr. Kellyann Kowalski¹, Dr. Jennifer Swanson²
1. University of Massachusetts Dartmouth, 2. Stonehill College

The Effective Support for Japanese Sojourner ELLs in American Schools
Ms. Michika Kato¹, Prof. Monica Flores¹, Prof. Tetsuo Yamada²
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Prof. Robert Clovey¹, Dr. William Raabe ²
1. York College - City University of New York (CUNY), 2. University of Wisconsin

VITA For All - The Many Possibilities for Students in A Business School
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A PROCESS FOR INTEGRATING INFORMATION TECHNOLOGY (IT) INTO THE ACCOUNTING CURRICULUM

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ABSTRACT

Accreditation from AACSB is considered one of the most prestigious achievable by higher educational business schools [2]. Currently there are 777 AACSB accredited institutions in 52 countries and territories who have earned the business accreditation. The AACSB offers a separate, additional accounting program accreditation to schools that earn the business accreditation. Currently there are 185 schools that have earned this dual accreditation. The number of schools applying for AACSB accreditation continues to grow beyond the first-tier national schools, as international, regional, and private schools perceive the need to become accredited [3].

The recent revisions to the Association to Advance Collegiate Schools of Business (AACSB) International standards introduces a new standard for earning the Accounting accreditation [1]. Standard A7 calls for “learning experiences that develop skills and knowledge related to the integration of information technology in accounting and business. Included in these learning experiences is the development of skills and knowledge related to data creation, data sharing, data analytics, data mining, data reporting, and storage within and across organizations.” [1].

The AACSB suggests that integrating these IT learning experiences into the curriculum should be an interdisciplinary approach. AACSB Accounting programs now need to demonstrate adherence to this standard for current and upcoming AACSB site visits. Due to the common nature of accounting programs throughout the U.S., whereby an outcome is to provide the educational requirements to facilitate eligibility for candidates interested in becoming licensed as Certified Public Accountants (CPAs), most accounting programs have very similar course requirements and content. Accounting degree programs typically include a single course in Accounting Information Systems (AIS) where, traditionally, most of IT-related content for the accounting curriculum has been covered. Sledgianowski, Gomaa, and Tan [2] suggest that skill-developing learning experiences required by Standard A7 can be integrated throughout a large part of the accounting curriculum using existing instructional resources.
This research-in-progress discusses a process we are using to integrate Big Data, and information systems and technologies into the curriculum of our accounting programs. The process we developed is driven by the department curriculum committee and involves faculty teaching the courses required of accounting majors, who help to identify the desired level of integration. The desired level of integration is based on available resources, faculty competencies and interest, compliance with accreditation requirements, influence of advisory boards, etc. The process includes conducting a gap analysis to identify the “as-is” current state of integration in the curriculum and the “to-be” of the desired integration.

To conduct a gap analysis, we developed a questionnaire to facilitate information collection from faculty. The questionnaire asks a set of questions designed to identify current and planned usage of information systems and technology in courses required of accounting majors to develop skills and knowledge of Big Data and business analytics. Next, the committee compares the current and planned usage with the desired state of integration. The difference is analyzed to identify areas for improved integration. The identified areas are candidates for inclusion of relevant instructional resources, such as those recommended in Sledgianowski et. al [2].

This research should be of interest to all institutions with accounting programs currently accredited by the AACSB as well as accreditation-aspiring institutions, and institutions looking to better integrate Big Data and other technologies into their curriculum.

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In accordance with Financial Accounting Standard 142, all entities are required to annually determine the potential impairment of its reported goodwill. This generally required a costly two-step procedure. Step one required the company to ascertain the fair market value of each of its reporting units. These reporting units are often not separately listed on any security exchange and had to be estimated using a variety of valuation models such as a discounted cash flow (DCF) method, or a fair market value approach. If the fair market value did not exceed the book value of the reporting unit’s net assets, the entity was required to determine the valuation of all of its assets and liabilities as if it were engaged in a hypothetical sale. The second procedure, referred to as “step 2,” required the significant cost of commissioning various valuation specialists.

In an effort to reduce the significant costs involved in the two step procedure, the FASB issued Accounting Standards Update 2011-08, Intangibles-Goodwill and Other (Topic 350): Testing Impairment of Goodwill. Under the provisions of the update, an entity is permitted to apply a “qualitative” approach, generally referred to as “step 0.” Entities were permitted to review a list of potential factors in determining if it was more likely than not (greater than 50%) that the carrying value of the reporting unit’s net assets exceeded its fair market value. Where a company passed the step 0 evaluation, it would be able to avoid the significant costs of steps 1 and 2, generally referred to as a “quantitative” process.

The Update listed the following determinants in the step 0 evaluation:

• Macroeconomic Conditions
• Industry and Market Considerations
• Cost Factors
• Overall Financial Performance
• Other Relevant Entity-Specific Events
• Events Affecting a Reporting Unit
• A Substantial decrease in Share Price (if applicable)

An entity would summarize the impact of these factors in determining whether it was “more likely than not” that a reporting unit’s carrying value exceeded its fair value.
A significant period has elapsed since the Financial Accounting Standards Board issued Accounting Standards Update 2011-08 (ASU 2011-08) where the potential cost savings may now be determined. The authors previously presented a longitudinal pilot study focusing on the Dow 30 companies for the reporting periods from 2011-2015 (Northeast Business and Economic 2016 Annual Conference). Although there was a progressive increase in the number of Dow 30 companies adopting the “qualitative” option, the majority of these companies were ambiguous in reporting the application of this cost savings provision. Furthermore, we found that the companies’ disclosure of using the option varied from clear and transparent to often ambiguous and ignored. The objective of this paper is to expand our study to all the registrants filed with the Securities Exchange Commission.

Research Design

The focus of this study is to examine the application of the qualitative option for all publicly listed companies, whether classified as large or small cap. The authors have selected a random sample of approximately 335 companies each year for reporting periods from 2011-2015 in determining the application of the qualitative option available under ASU 2011-08. We are interested if the range of diverse disclosures of goodwill impairment found in the Dow 30 companies are also found in all classes of registrants with the SEC. We will be specifically examining the following hypotheses:

**H1a**: More companies will not adopt the ASU update in order to minimize the costs involved in accounting for goodwill impairment.

**H1b**: More companies will adopt the ASU update in order to minimize the costs involved in accounting for goodwill impairment.

**H2a**: More companies will not adopt the ASU update in 2015 than in 2011.

**H2b**: More companies will adopt the ASU update in 2015 than in 2011.

The 10-K reports of the sampled companies will be examined for fiscal years 2011 and 2015 to determine the adoption of the new qualitative assessment option. The sample companies are selected from the lists of companies reported by Compustat.

In summary, the focus of the current study will determine if there has been an increase in the adoption of the qualitative option by SEC registrants in the measurement of goodwill impairment. In addition, we will examine the range of the of disclosures of using the qualitative option. Specifically, the disclosures will be classified from clear/transparent to ambiguous and/or completely ignored.
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Earnings Announcement Timing as a Signal of Potential Earnings Management

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ABSTRACT: We examine the differences between the unexpected returns of firms reporting earnings early and firms reporting earnings late, and argue that the differences reflect the market’s initial assessment of a higher probability of earnings management for late reporters relative to early reporters. The subsequent release of the full set of financial statements in SEC filings provides the market with the necessary financial information to adjust its initial estimate of the probability the firm engaged in earnings management. We thus expect the association between unexpected returns over a short window centered on the SEC filing date and unexpected abnormal accruals to be dependent on whether the firm reported earnings early or late. Consistent with our expectations, we find higher returns around the SEC filing date for late earnings reporting firms with relatively low unexpected accruals relative to early reporting firms with relatively low unexpected accruals, and lower returns for early earnings reporting firms with relatively high unexpected accruals relative to late reporting firms with relatively high unexpected accruals.
1. Introduction

Accounting researchers have offered various definitions of earnings management over the years. For example, Schipper [1989] defines earnings management as the purposeful intervention in the external reporting process, with the intent of obtaining some private gain (as opposed to merely facilitating the neutral operation of the process). Healy and Whalen [1999, 368] describe earnings management as “alter(ing) financial reports to either mislead some stakeholders about the underlying economic performance of the company or to influence contractual outcomes that depend on reported accounting numbers”. Finally, Dechow and Skinner [2000] argue that some judgments and accounting practices that conform to GAAP may be considered earnings management if managerial intent is to obscure the true economic performance of the firm. Regardless of the specifics, all of these definitions agree that earnings management is a deliberate obscuring of the true economic performance of the firm, likely for the private gain of management.

Researchers have examined motivations that drive management to obscure performance and mislead stakeholders. Additionally, they have constructed models that successfully detect either levels of abnormal accruals or abnormal earnings distributions and have concluded that either will indicate the presence of earnings management.¹ We accept the premise that some firms manipulate their reported earnings through earnings

management. Based on Trueman [1990], we propose that late announcing firms have a higher likelihood of managing earnings and argue that the market’s assessment of the probability of earnings management is revealed through the difference in the common stock returns between early and late reporting firms. Management's timing of an earnings announcement is a discretionary decision, regardless of whether the release itself is voluntary or mandatory. Trueman’s [1990] theory could thus be considered an extension of the abnormal accrual literature. We empirically test the theory that the market compares the timing of a firm’s earnings announcement relative to the timing of the announcements of other industry member firms as an indication of potential earnings management.

Our results indicate that cumulative unexpected returns (CSUR) for early reporting firms are more positive than CSUR for late reporting firms, consistent with the argument that the market assesses a higher probability of earnings management to late earnings announcements and discounts late earnings reports. Supporting our early/late hypothesis, we find a greater percentage of high abnormal accruals associated with late earnings announcers relative to early announcers.

We also extend the work of Balsam, et al. [2002] on the market reactions to financial report filings with the Securities and Exchange Commission (SEC) by predicting the movement of stock prices based on the timing of earnings announcements and the level of unexpected abnormal accruals. The SEC filings provide information to support or adjust the assessed probability of earnings management based on the timing of the firm’s earnings announcement. We find that the CSUR of firms with relatively high unexpected abnormal
accruals surrounding SEC filings are greater for late earnings announcing firms relative to early announcing firms. These results are consistent with the notion that the market assessed a lower probability of earnings management to early reporting firms, and adjusts the assessment after the information in the SEC filing becomes available. We find that late announcing firms with low abnormal accruals have more positive price reactions than early announcing firms with low abnormal accruals. Our results are consistent with the notion that the market assigns a higher probability of earnings management to late reporting firms and adjusts this assessment when information from the SEC filing becomes available.

Our paper contributes to the literature by providing an insight of why the timing of earnings announcements relative to other industry members influences stock price reactions surrounding both the earnings report date and the SEC filing date.

2. Hypotheses Development

Trueman [1990] bases his assertions on the results of prior researchers’ tests of the association between early-late reports and good-bad news. Early (late) reports in these studies are defined as earnings announcements that arrive before (after) either last period's report date or an expected report date (i.e., based on a time-series model). Good (bad) news represents higher (lower) than expected earnings or positive (negative) abnormal stock returns. Givoly and Palmon [1982], Chambers and Penman [1984], and Penman [1984] find that earlier (later) than expected reports are associated with positive (negative) abnormal returns, supporting the good news early-bad news late reporting hypothesis. Kross and Schroeder [1984] report significantly higher market returns for early announcements.
reporting moderately good or moderately bad unexpected earnings compared to late announcements containing similar news. Bagnoli, et al. [2002] report that the market’s response to earnings announcements depends on the timing of the announcement relative to the firm’s expected report date. Their results offer evidence that timing conveys or correlates with information distinct from the sign and size of unexpected earnings, and suggest that, keeping unexpected earnings constant, the earlier the report date, the more positive the market reaction.

Trueman’s [1990] model of earnings announcement timing is consistent with reported empirical findings, and offers additional predictions of the effects of intraindustry relationships on these findings. The model assumes investors interpret the characteristics of earnings reports to translate accounting earnings into economic earnings. These characteristics include (1) the magnitude of accounting earnings and (2) the timing of the announcement relative to the other firms in the industry earnings release queue. Trueman's [1990] assumption of nonrandom report timing is consistent with recent grounded, inductive theory in the voluntary disclosure area. Gibbins, et al. [1990] identify the disclosed information, its interpretation, and its timing as manageable attributes of disclosure. Trueman [1990] further assumes that some managers may choose to manipulate accounting earnings released during a given period.

Trueman [1990] argues that managers report good news early if economic earnings are good or report bad news early if economic earnings are bad and no attempt is made to manage earnings. Managers report good news late if unable to report early, or report bad
news late if economic earnings are bad and the manager decides not to manage earnings. Some reporting delays are outside manager’s control and preclude earnings management. Whittred [1980] finds a relationship between qualified audit reports and earnings report timing.

Managers contemplating earnings management have the option of reporting earnings before the returns of other industry firms becomes known or reporting earnings after the returns of other industry firms becomes known. A late good news accounting report will be more (less) credible in the presence of high (low) overall industry earnings. Managers contemplating earnings management may wait until after the returns of early announcers indicate high overall industry earnings before managing earnings and reporting good news.

A basic result of this analysis is that, given a positive probability of an earnings report delay for earnings management purposes, early announcements will result in more positive returns than later announcements. Trueman’s [1990] theory suggests that investors react positively to good news accounting earnings, but discount late reports somewhat due to the higher possibility of earnings management. Trueman [1990] extends prior results by noting that the magnitude of the discount is a function of investors' assessment of the probability that the delay in reporting was due to earnings management rather than to factors outside of management control.

Trueman’s [1990] model of earnings management allows the formulation of hypotheses to test the effect of the firm’s position in its industry earnings release queue on the market’s reaction to its earnings announcement. Given a positive probability of delay due to earnings
management, the model predicts that the average unexpected returns will be greater for firms reporting early in the earnings release queue than for those reporting late. This leads to the following hypothesis (all hypotheses are in the alternate form):

H1: Unexpected returns surrounding the earnings report dates for firms reporting early in the earnings release queue are greater than the unexpected returns of firms announcing late in the earnings release queue.

We argue that the market’s assessment of the probability of earnings management is adjusted when the full set of financial statements becomes available with the filing of SEC reports. Early reporting firms are initially assigned a lower probability of earnings management and are expected to have relatively low abnormal accruals (both low positive and low negative abnormal accruals). We predict the market will act negatively to early reporting firms with relatively high positive or negative abnormal accruals. Therefore, late reporting firms with relatively high positive or negative abnormal accruals are also expected to have higher returns than early reporting firms with relatively high positive or negative abnormal accruals. Late reporting firms are assigned a higher probability of earnings management, and are expected to have relatively high positive or negative abnormal accruals. We predict the market will react positively to late reporting firms with relatively low abnormal accruals. Therefore, late reporting firms with relatively low abnormal accruals are expected to have higher returns than early reporting firms with relatively low abnormal accruals. This leads to the following hypotheses:
H2: The returns of firms reporting late in the earnings release queue with relatively high positive abnormal accruals are greater than the returns of firms reporting early in the earnings release queue with relatively high positive abnormal accruals.

H3: The returns of firms reporting late in the earnings release queue with relatively low abnormal accruals are greater than the returns of firms reporting early with relatively low discretionary accruals.

H4: The returns of firms reporting late in the earnings release queue with relatively high negative abnormal accruals are greater than the returns of firms reporting early in the earnings release queue with relatively high negative abnormal accruals.

3. Sample Selection

The sample initially consists of all four-digit Standard Industrial Classification (SIC) code classification industries with at least four December 31 fiscal year-end companies excluding utilities and financial services firms (four-digit SIC codes 4900-4999 and 6000-6799) with complete data for the following items in any of the forty-three quarters from the first quarter of 1994 through the third quarter of 2004:

1. Primary earnings per share before extraordinary items, revenues, net receivables, gross property, plant, and equipment, current assets, current liabilities, cash/cash equivalent, debt included in current liabilities, and depreciation and amortization expense available on the Standard and Poor’s Compustat database (Compustat).
2. Announcement dates of quarterly earnings available on I/B/E/S or Compustat.
The sample was further reduced to include the above firm-quarter observations that have:

4. SEC reporting dates available on the SEC’s Electronic Data Gathering, Analysis, and Retrieval system (EDGAR).
6. Daily returns data available on the CRSP files (returns reported as missing are assigned the value zero). Chandra [1992] uses this method to address missing returns. An alternative approach, used by Brown and Warner [1985], excludes both the day of the missing return and the return for the subsequent trading day.

The final sample consists of 6,019 firm-quarter observations and includes 36 four-digit SIC code industries.

4. Research Design

4.1 Variable Estimation

For each firm i’s earnings announcement during quarter q in the test period unexpected earnings (UE_{iq}) is measured as the difference between the I/B/E/S forecasted earnings per share (FE_{iq}) and actual earnings per share (AE_{iq}), deflated by the share price on the last day of the previous quarter (P_{iq-1}). Additional deflators used in prior research include forecasted earnings and the standard deviation of analysts’ forecast errors for the firm-quarter observations, however, Kothari [1992] notes that the systematic risk estimate is less biased when price instead of earnings is the deflator. Therefore, we use price as our deflator, and
unexpected earnings is estimated using equation (1):

\[ UE_{iq} = \frac{AE_{iq} - FE_{iq}}{P_{iq-1}}. \] (1)

Firm specific market model parameters are then estimated using equation (2):

\[ R_{it} = \alpha_i + \beta_i R_{mt} + \epsilon_{it} \] (2)

where \( R_{it} \) is the return for firm \( i \) on day \( t \), and \( R_{mt} \) is the equally weighted market return for day \( t \). We define day zero as the date of the quarterly earnings announcement and estimate the parameters of equation (2) over trading days -259 to -60 for each firm for each of the firm-quarter observations in the test period. Standardized unexpected returns are then computed for each firm-quarter observation using equation (2) parameter estimates in equation (3):

\[ SUR_{it} = \frac{R_{it} - (\alpha_i + \beta_i R_{mt})}{\sigma_{ei}} \] (3)

where for each quarter \( SUR_{it} \) is the standardized unexpected return for firm \( i \) on day \( t \) during the quarter, and \( \sigma_{ei} \) is the standard deviation of the market model residuals for firm \( i \) over the estimation period (trading days -256 to -60). The \( SUR_{it} \) for each firm in an industry are computed from two days before until two days after day zero. The \( SUR_{it} \) for each firm in each quarter are then summed to obtain \( CSUR_{iq} \).

4.2 Test of Hypothesis 1

To test the effect of the firm’s position in the earnings release queue (PERQ) on returns, the model developed by Brown et al. [1994] to determine the impact of timing on the
information content of earnings is extended to include the effects of the timing of the earnings announcement (early or late), the type of news (good or bad), and firm size. The Brown et al. [1994] model, based on the conceptual work of Kim and Verrecchia [1991], is:

$$\text{CSUR}_{iq} = b_0 + (b_1 + b_2 \text{DAYS}_q)\text{UE}_{iq} + \epsilon_{iq}$$  \hspace{1cm} (4)

where $\text{CSUR}_{iq}$ is as previously defined, DAYS$_q$ is the number of calendar days elapsed between the end of quarter $q$ and the earnings announcement date for firm $i$ in quarter $q$, and the expression $(b_1 + b_2 \text{DAYS}_q)$ is the information content of unexpected earnings for a given level of DAYS. The coefficient $b_2$ in the model measures the impact of timing on the information content of earnings. Brown et al. [1994] partition their sample by firm size, and examine separate regressions for each firm size to determine if firm size effects the response to the timing of earnings announcements.

We extend Equation (4) as follows to include the effects of timing, unexpected earnings, and firm size:

$$\text{CSUR}_{iq} = \phi_0 + (\phi_1 + \phi_2 \text{SMALL}_{iq} + \phi_3 \text{LARGE}_{iq})\text{TIMING}_{iq} +$$
$$+ (\phi_4 + \phi_5 \text{SMALL}_{iq} + \phi_6 \text{LARGE}_{iq})\text{UE}_{iq} +$$
$$+ (\phi_7 + \phi_8 \text{SMALL}_{iq} + \phi_9 \text{LARGE}_{iq})\text{UE}_{iq} \times \text{TIMING}_{iq} + \epsilon_{iq}$$  \hspace{1cm} (5)

where TIMING is a dichotomous variable that equals zero if firms are classified as early (the PERQ for firm $i$ in quarter $q$ is in the first half of the industry queue) or one if firms are classified late (the PERQ for firm $i$ in quarter $q$ is in the last half of the industry queue), UE$_{iq}$ is the unexpected earnings for firm $i$ in quarter $q$ as estimated by equation (1), SMALL$_{iq}$ is
an indicator variable that equals one if firm \( i \) in quarter \( q \) is in the lowest two size deciles and is zero otherwise, and \( \text{LARGE}_{iq} \) is an indicator variable that equals one if firm \( i \) in quarter \( q \) is in the highest two size deciles and is zero otherwise.

In equation (5), \( \phi_0 \) and the coefficient on \( \text{UE} \), \( \phi_4 \), represent the intercept and slope parameters of the regression line for firms announcing early. Both \( \phi_0 \) and \( \phi_4 \) are expected to be positive. The incremental effect on CSUR of late announcers is represented by the coefficient on \( \text{TIMING} \), \( \phi_1 \), and is expected to be negative. The incremental effects of small firms announcing late is represented by the coefficient on the interaction term \( \text{SMALL} \times \text{TIMING} \), \( \phi_2 \), and of large firms announcing late by the coefficient on the interaction term \( \text{LARGE} \times \text{TIMING} \), \( \phi_3 \). The incremental effect on CSUR of the unexpected earnings of small firms is represented by the coefficient on the interaction term \( \text{SMALL} \times \text{UE} \), \( \phi_5 \). The incremental effect on CSUR of the unexpected earnings of large firms is represented by the coefficient on the interaction term \( \text{LARGE} \times \text{UE} \), \( \phi_6 \). The effect of unexpected earnings of late announcing firms is represented by the coefficient on the interaction term \( \text{TIMING} \times \text{UE} \), \( \phi_7 \). The incremental effects on CSUR of small firms announcing earnings late is represented by the coefficient on the three-way interaction term \( \text{SMALL} \times \text{UE} \times \text{TIMING} \), \( \phi_8 \), and of large firms announcing late by the coefficient on the three-way interaction term \( \text{LARGE} \times \text{UE} \times \text{TIMING} \), \( \phi_9 \).
4.3 Tests of Hypotheses 2, 3, and 4

Hypotheses 2, 3, and 4 predict an association between the difference in unexpected returns of early and late reporting firms and the level of abnormal accruals (H2 focuses on high positive abnormal accruals, H3 focuses on low abnormal accruals, and H4 focuses on high negative abnormal accruals). Testing these hypotheses requires measuring proxies for abnormal accruals. We use the modified Jones model to estimate abnormal accruals. In the Jones model, normal accruals are defined as:

\[ \text{NA}_{iq} = \alpha_1 + \alpha_2 (\Delta \text{REV}_{iq} - \Delta \text{REC}_{iq}) + \alpha_3 \text{PPE}_{iq} \]  

where

\( \text{NA}_{iq} \) = normal accruals for firm \( i \) for quarter \( q \),

\( \Delta \text{REV}_{iq} \) = revenues in quarter \( q \) less revenues in quarter \( q-1 \) for firm \( i \),

\( \Delta \text{REC}_{iq} \) = net receivables in quarter \( q \) less net receivables in quarter \( q-1 \) for firm \( i \),

and

\( \text{PPE}_{iq} \) = gross property, plant, and equipment for firm \( i \) in quarter \( q \).

All variables are scaled by total lagged assets \( (A_{q-1}) \). Jones [1991] includes the change in revenues in her model to control for the economic environment of the firm. Dechow, et al. [1995] argue that this implicitly suggests that all changes in revenues are normal. They modeled the abnormal component of the change in revenues as the change in receivables; thus, they assumed all changes in receivables are abnormal and all changes in revenues not associated with the change in receivables are normal. Jones [1991] includes
gross property, plant, and equipment to control for abnormal depreciation expense. The complete modified Jones model is therefore:

$$\Delta T_{A_iq} = \alpha_1 + \alpha_2 (\Delta R_{E iq} - \Delta R_{C iq}) + \alpha_3 P_{PE iq} + v_{iq}$$  \hspace{1cm} (7)$$

where $\Delta T_{A_iq}$ equals the change in total accruals for firm $i$ between quarter $q-1$ and $q$, scaled by total lagged assets. Total accruals are defined as:

$$T_{A_iq} = \Delta C_{A_iq} - \Delta C_{L_iq} - \Delta C_{ash_iq} + \Delta S_{TD_iq} - D_{EP_iq}$$  \hspace{1cm} (8)$$

where

$T_{A_iq}$ = Total accruals for firm $i$ for quarter $q$,
$\Delta C_{A_iq}$ = Change in current assets for firm $i$ from quarter $q-1$ to quarter $q$ ,
$\Delta C_{L_iq}$ = Change in current liabilities for firm $i$ from quarter $q-1$ to quarter $q$,
$\Delta C_{ash_iq}$ = Change in cash/cash equivalents for firm $i$ from quarter $q-1$ to quarter $q$,
$\Delta S_{TD_iq}$ = Change in debt included in current liabilities for firm $i$ from quarter $q-1$ to quarter $q$, and
$D_{EP_iq}$ = Depreciation and amortization expense for firm $i$ for quarter $q$.

Total accruals equal the sum of normal and abnormal accruals; therefore, abnormal accruals can be estimated as:

$$A_{A_iq} = T_{A_iq} - [\alpha_{1t} + \alpha_2 (\Delta R_{E iq} - \Delta R_{C iq}) + \alpha_3 P_{PE iq}]$$  \hspace{1cm} (9)$$

The residual from equation (7), $v_{iq}$, can be used to proxy for abnormal accruals (AAP).

Prior research does not provide guidance on the level of abnormal accruals that
indicate earnings management, only that relatively larger abnormal accruals indicate a greater likelihood of earnings management. We partition AAP into deciles, and assign the upper decile as the proxy for high positive abnormal accruals, and the lowest decile as the proxy for high negative abnormal accruals.

The model used to examine the impact on share price of the timing of earnings announcements and the level of abnormal accruals on SEC reporting dates is:

$$CSUR_{iq} = \beta_0 + \beta_1 \text{TIMING}_{iq} + (\beta_2 + \beta_3 \text{TIMING}_{iq}) \text{AAP}_{iq} + (\beta_4 \text{LAAP}_{iq} + \beta_5 \text{HDAP}_{iq} \text{DAP}_{iq} + (\beta_6 \text{LDAP}_{iq} + \beta_7 \text{HAAP}_{iq} \text{AAP}_{iq} \text{TIMING}_{iq} + \epsilon_{iq}$$

(10)

where CSUR_{iq} is the cumulative abnormal return for firm i in quarter q from two days before firm i’s SEC filing date until two days after the SEC filing, TIMING and DAP_{iq} are as previously defined, LAAP_{iq} a dichotomous variable that equals one if AAP for firm i in quarter q is in the lowest decile, and zero otherwise, and HAAP_{iq} is a dichotomous variable that equals one if AAP for firm i in quarter q is in the highest decile, and zero otherwise.

In equation (10), \beta_0 represents the intercept term for firms announcing their earnings early, and the coefficient on TIMING, \beta_1, represents the difference in the intercepts between early and late announcing firms. A significantly negative coefficient on timing would indicate that the market continues to discount the information disclosures of late announcing firms relative to early announcing firms. Relatively low abnormal accruals are associated with a lower probability of earnings management, and the effect of the abnormal accruals on
share price is reflected in the coefficient on AAP, $\beta_2$, and is predicted to be positive. The coefficient on the interaction term TIMING*AAP, $\beta_3$, represents the difference in returns between early and late announcing firms reporting relatively low abnormal accruals and is predicted to be positive (H3). The marginal effect of relatively low negative abnormal accruals (income decreasing) of early reporting firms is captured in the coefficient on LAAP*AAP, $\beta_4$, and is predicted to be negative. The marginal effect of relatively high positive abnormal accruals (income increasing) of early reporting firms is captured in the coefficient on HAAP*AAP, $\beta_5$ and is also predicted to be negative (H2). The marginal effect of relatively high negative abnormal accruals (income decreasing) of late reporting firms is captured in the coefficient on LAAP*AAP*TIMING, $\beta_6$, and is predicted to be positive (H4). The marginal effect of relatively high positive abnormal accruals (income increasing) of late reporting firms is captured in the coefficient on HAAP*AAP*TIMING, $\beta_7$, and is also expected to be positive (H2).

5. Results

The first hypothesis (H1) predicts that the magnitude of unexpected returns for firms reporting early in the industry earnings release queue is greater than the magnitude of unexpected returns for early reporting firms. The hypothesis is tested by regressing cumulative standardized unexpected returns (CSUR) on unexpected earnings (UE), an indicator variable (TIMING) that equals one if the firm’s PERQ is in the last half of the
industry ERQ, and zero if the firm’s PERQ is in the first half of the industry ERQ, the interaction between UE and TIMING, the three-way interaction between UE, TIMING, and an indicator variable (NEGUE) that equals one if UE is negative and zero otherwise, and the three-way interaction between UE, TIMING, and an indicator variable (POSUE) that equals one if UE is positive and zero otherwise. Our results, presented in Table 1, show a significantly negative TIMING coefficient (p-value = 0.0015) implying smaller unexpected cumulative returns of late versus early reporting firms. The results are consistent with prior studies and support Trueman’s [1990] theory that given a positive probability of delay due to earnings management, the average unexpected returns is greater for firms reporting early in the ERQ than for those reporting later in the ERQ.

Hypotheses 2 through 4 are tested using parameter estimates obtained by regressing cumulative standardized unexpected returns on TIMING, UE, abnormal accruals (AAP), the interaction between TIMING and AAP, the interaction between AAP and relatively high negative discretionary accruals (LAAP), the interaction between AAP and high positive discretionary accruals (HAAP), and the three-way interactions AAP*TIMING*LAAP and AAP*TIMING*HAAP. The second hypothesis (H2) predicts that the returns of firms reporting late in the ERQ with relatively high positive abnormal accruals are greater than the returns of early reporting firms with relatively high positive abnormal accruals. H2 is supported if the coefficient on the interaction term between AAP and HAAP, $\beta_5$, is negative.
and the coefficient on the interaction term between DAP, HDAP and TIMING, $\beta_7$, is positive. Table 2 presents results consistent with the predictions for H2. The coefficient on AAP*HAAP is significantly negative (p-value = 0.0053) and the coefficient on AAP*HAAP*TIMING is significantly positive (p-value = 0.0343), indicating that surrounding the SEC reporting date, early reporting firms with relatively high positive abnormal accruals have lower returns than late reporting firms with relatively high positive abnormal accruals.

The third hypothesis (H3) predicts that the returns of firms reporting late in the ERQ with relatively low abnormal accruals are greater than the returns of early reporting firms with relatively low abnormal accruals. H3 is supported if the coefficient on the interaction term between AAP and TIMING, $\beta_3$, is positive. Table 2 presents results inconsistent with the predictions for H3. The coefficient on AAP*TIMING is significantly negative (p-value = 0.0330). Additionally, the coefficient on AAP is significantly positive (p-value = 0.0060), indicating that surrounding the SEC reporting date, early reporting firms with relatively low abnormal accruals have higher returns than late announcing firms with relatively low abnormal accruals.

The fourth hypothesis (H4) predicts that the returns of firms reporting late in the ERQ with relatively high negative abnormal accruals are greater than the returns of early reporting firms with relatively high negative abnormal accruals. H4 is supported if the coefficient on the interaction term between AAP and LAAP, $\beta_4$, is negative, and the coefficient on the...
interaction term between AAP, LAAP and TIMING, $\beta_6$, is positive. Table 2 presents results consistent with the predictions for H4. The coefficient on AAP*LAAP is significantly negative (p-value = 0.0036) and the coefficient on AAP*LAAP*TIMING is significantly positive (p-value = 0.0298), indicating that surrounding the SEC reporting date, early reporting firms with relatively high negative abnormal accruals have lower returns than late announcing firms with relatively high negative abnormal accruals.

[Insert Table 2]

Our results indicate that the market reacts to information released in the SEC reports differently for firms depending on whether the firm reported earnings early or late in its respective industry ERQ. The significantly negative coefficient on TIMING reported in Table 2 (p-value = .0284), and the failure to reject H3 indicate that late reporters’ “good news” information continues to be discounted relative to early announcers. The market reacts negatively to unexpected high positive or high negative abnormal accruals of early reporters relative to late reporters, who were expected to have high positive or high negative abnormal accruals.

6. Conclusion

We test the hypothesis that the timing of a firm's earnings announcement relative to other members of the firm’s industry is used by the market as an indicator of possible earnings management. Under the hypothesis, the market's reaction to the earnings of late announcing firms will be weaker than the relative reaction to early announcing firms. We also predict
expected market reactions to the firm’s SEC disclosures depending on whether the
disclosures confirmed or contradict the market's initial assignment of the probability of a firm
engaging in earnings management. Our findings are consistent with the concept that the
market reacts negatively to firm information that negatively contradicts its initial
expectations for the firm, and reacts positively to information that confirms its initial
expectations. Future research may wish to more fully investigate the role that earnings
announcement timing has on the market’s reaction to firm information.
REFERENCES


Levitt, A. The numbers game, Speech at the NYU Center for Law and Business (1998).


TABLE 1: Results of Hypothesis 1 Regression

\[
\text{CSUR}_{iq} = \beta_0 + (\beta_1 + \beta_2 \text{SMALL}_{iq} + \beta_3 \text{LARGE}_{iq}) \text{TIMING}_{iq} + \\
(\beta_4 + \beta_5 \text{SMALL}_{iq} + \beta_6 \text{LARGE}_{iq}) \text{UE}_{iq} + \\
(\beta_7 + \beta_8 \text{SMALL}_{iq} + \beta_9 \text{LARGE}_{iq}) \text{UE}_{iq} \times \text{TIMING}_{iq} + \epsilon_{iq}
\]

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\( \text{CSUR}_{iq} \): Cumulative standardized unexpected returns for firm \( i \) from one day before the firm announces its quarterly earnings until one day after firm \( i \) announces its earnings.

\( \text{SMALL}_{iq} \): An indicator variable that equals one if firm \( i \) in quarter \( q \) is in the lowest size decile, and zero otherwise.

\( \text{LARGE}_{iq} \): An indicator variable that equals one if firm \( i \) in quarter \( q \) is in the largest size decile, and zero otherwise.

\( \text{TIMING}_{iq} \): An indicator variable that equals one of the PERQ for firm \( i \) in quarter \( q \) is in the last half for its industry, or zero if the PERQ is in the first half for its industry.

\( \text{UE}_{iq} \): Actual earnings minus forecasted earnings, deflated by share price.
### TABLE 2: Results of Hypotheses 2, 3 and 4 Regression

\[
\text{CSUR}_{iq} = \beta_0 + \beta_1 \text{TIMING}_{iq} + (\beta_2 + \beta_3 \text{TIMING}_{iq}) \text{AAP}_{iq} + (\beta_4 \text{LAAP}_{iq} + \beta_5 \text{HAAP}_{iq}) \text{AAP}_{iq} \times \text{TIMING}_{iq} + \epsilon_{iq}
\]

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<td>0.0806</td>
<td>3.3677</td>
<td>-3.8748</td>
<td>-5.2523</td>
<td>5100</td>
<td>2.79</td>
</tr>
<tr>
<td>t-statistics</td>
<td>(3.18)</td>
<td>(-2.14)</td>
<td>(-1.52)</td>
<td>(1.57)</td>
<td>(0.34)</td>
<td>(1.60)</td>
<td>(-1.16)</td>
<td>(-1.75)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>p-values</td>
<td>0.0015</td>
<td>0.0322</td>
<td>0.366</td>
<td>0.893</td>
<td>&lt;0.0001</td>
<td>0.063</td>
<td>0.1222</td>
<td>0.0401</td>
<td></td>
<td>&lt;0.0068</td>
</tr>
</tbody>
</table>

**CSUR_{iq}** Cumulative standardized unexpected returns for firm i from two days before the firm files its SEC report until two days after the firm files the SEC report.

**TIMING_{iq}** A dummy variable that equals one of the PERQ for firm i in quarter q is in the last half for its industry, or zero if the PERQ is in the first half for its industry.

**AAP_{iq}** Proxy for abnormal accruals for firm i in quarter q.

**LAAP_{iq}** An indicator variable that equals one if AAP for firm i in quarter q is in the lowest decile, and zero otherwise.

**HAAP_{iq}** An indicator variable that equals one if AAP for firm i in quarter q is in the upper decile, and zero otherwise.
Business firms have a reasonably strong incentive to reincorporate in a non-domestic taxing jurisdiction as a means of creating shareholder value through lower taxes on net income. Since tax payments on profit are merely a distributional sharing of net operating results with non-owners, such a strategy has intuitive appeal as a presumably costless technique to increase net cash flow from operations. Furthermore, managers may well see this type of exploit as a riskless way to enhance their own wealth—since their remuneration likely is tied, in some manner, to after-tax “bottom line” profitability. Actions of this sort typically are called tax inversions.

This research reports on an investigation of whether low-tax-rate jurisdiction shopping practices actually create value for owners. By using case examples, developed from a recent 5-year period, an analysis is conducted of returns on assets to determine if the simple act of tax jurisdiction realignment leads to enterprise value enhancement.

The focus is on a single country’s inversions that were completed between 2010 and 2014. This limited scope was selected to assure that the work is contemporary and relevant, while maintaining accessibility to financial data from the post-inversion period. The project examines the impact from the lowest corporate tax rate country among developed nations, providing a strong likelihood of uncovering artificial value creation that can come as a consequence of tax avoidance. An investigation focused on one country also limits complications caused by possible discrepancies in law.

Results from this research should be of interest to governmental units, policy makers, corporate management, and investing stakeholders. If inversions create shareholder value at the margin, then such financial engineering might well lead to a significant world-wide migration of headquarters for many large multi-national business enterprises. Artificial value creation, in effect, could engender market disruptions and an altered geographic dispersion of financial power.
A Case Study of Statistics for a MBA Course
– Regarding Polls of the 2016 Presidential Election

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ABSTRACT

This case study is to reinforce students’ knowledge and skills of statistics by analyzing twenty polls before the 2016 Presidential Election. Students are required to calculate sample standard deviations, error of margins, and confidence intervals; and to do statistical inference and hypothesis testing. This case study shows the difference between a sample and the population from which the sample is drawn, illustrates the chance of error when extending the result of a sample to the population, and enhances students’ understanding on the meaning of statistical analysis. This case study has been used in Managerial Decision Analysis, a MBA course, a week after the Presidential Election, and students were engaged very actively.

Managerial Decision Analysis is a MBA course in School of Business. It covers statistics, decision theory, game theory, and mathematical programming. In the first two class meetings of Fall 2016, we reviewed statistics topics such as sample drawing, statistical inference, hypothesis testing, and determining the adequate sample size.

This case was developed right after the 2016 Presidential Election in November. The result of the election was opposite to almost all polls before the election. People were stunned and perplexed, and wondered whether there was something wrong in the media polls. The purpose of this case study is to let students statistically analyze the poll results and reinforce what students have learned in statistics by using a scenario that every student has just experienced.

I. Description of the Case.

I.1 The purposes of this case study include:
(1) Recognizing that most poll results of media did not provide complete information. Particularly, the errors of margin and confidence levels were missing.
(2) Reinforcing students understanding of statistics concepts of samples and population.
(3) Technically applying the methods students have learned for statistical analysis.
(4) Analyzing the validity and randomness of a sample.
(5) Clarifying some misunderstandings of statistical results.
Statistics is investigating what a population is like from a sample of it. In most real-world applications of statistics, one can calculate confidence intervals where population proportions may stay, but one never knows the exact values of the population proportions. This case is rare in the sense that we have eventually known the population proportion which was shown in the voting results. With such a case, students can compare the results of samples (polls) and statistical inference based on the samples with what the population (nation-wide voting result) is actually like, so that they could have a solid idea on what statistics is.

1.2 Data


Table 1. Twenty Polls of media before 2016 Presidential Election

<table>
<thead>
<tr>
<th>#</th>
<th>Polling Date</th>
<th>Source</th>
<th>Type of polling</th>
<th>Sample size, n</th>
<th>Clinton sample %</th>
<th>Trump sample %</th>
<th>Who leads in sample?</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>11/4-7</td>
<td>YouGovt/Economist</td>
<td>Online</td>
<td>3669</td>
<td>45%</td>
<td>41%</td>
<td>Clinton</td>
</tr>
<tr>
<td>2</td>
<td>11/4-7</td>
<td>IBD/TIPP</td>
<td>Live phone</td>
<td>1107</td>
<td>41%</td>
<td>43%</td>
<td>Trump</td>
</tr>
<tr>
<td>3</td>
<td>11/4-7</td>
<td>Insight West</td>
<td>Online</td>
<td>940</td>
<td>45%</td>
<td>41%</td>
<td>Clinton</td>
</tr>
<tr>
<td>4</td>
<td>11/4-6</td>
<td>Bloomberg/Selzer</td>
<td>Live phone</td>
<td>799</td>
<td>46%</td>
<td>43%</td>
<td>Clinton</td>
</tr>
<tr>
<td>5</td>
<td>11/4-6</td>
<td>Lucid/The Time-Picayune</td>
<td>Online</td>
<td>931</td>
<td>45%</td>
<td>40%</td>
<td>Clinton</td>
</tr>
<tr>
<td>6</td>
<td>11/3-6</td>
<td>Fox News</td>
<td>Live phone</td>
<td>1295</td>
<td>48%</td>
<td>44%</td>
<td>Clinton</td>
</tr>
<tr>
<td>7</td>
<td>11/3-6</td>
<td>Monmouth University</td>
<td>Live phone</td>
<td>748</td>
<td>50%</td>
<td>44%</td>
<td>Clinton</td>
</tr>
<tr>
<td>8</td>
<td>11/3-6</td>
<td>ABC News / Wash'tn Post</td>
<td>Live phone</td>
<td>2220</td>
<td>47%</td>
<td>43%</td>
<td>Clinton</td>
</tr>
<tr>
<td>9</td>
<td>11/2-6</td>
<td>NY Times / CBS News</td>
<td>Live phone</td>
<td>1426</td>
<td>47%</td>
<td>43%</td>
<td>Clinton</td>
</tr>
<tr>
<td>10</td>
<td>10/31-11/6</td>
<td>NBC News / SurveyMonkey</td>
<td>Online</td>
<td>70194</td>
<td>47%</td>
<td>41%</td>
<td>Clinton</td>
</tr>
<tr>
<td>11</td>
<td>11/2-6</td>
<td>Rasmussen</td>
<td>IVR/online</td>
<td>1500</td>
<td>45%</td>
<td>43%</td>
<td>Clinton</td>
</tr>
<tr>
<td>12</td>
<td>11/2-6</td>
<td>Ipsos/Reuters</td>
<td>Online</td>
<td>2195</td>
<td>42%</td>
<td>39%</td>
<td>Clinton</td>
</tr>
<tr>
<td>13</td>
<td>10/31-11/6</td>
<td>UPI/Cvoter</td>
<td>Online</td>
<td>1625</td>
<td>49%</td>
<td>46%</td>
<td>Clinton</td>
</tr>
<tr>
<td>14</td>
<td>11/4-5</td>
<td>Politico/Morning Consult</td>
<td>Online</td>
<td>1482</td>
<td>45%</td>
<td>42%</td>
<td>Clinton</td>
</tr>
<tr>
<td>15</td>
<td>11/3-5</td>
<td>NBC News / WSJ</td>
<td>Live phone</td>
<td>1282</td>
<td>44%</td>
<td>40%</td>
<td>Clinton</td>
</tr>
<tr>
<td>16</td>
<td>11/3-5</td>
<td>Franklin Pierce/RKM/Boston Herald</td>
<td>Live phone</td>
<td>1009</td>
<td>48%</td>
<td>44%</td>
<td>Clinton</td>
</tr>
<tr>
<td>17</td>
<td>11/1-4</td>
<td>Angus Reid/MARU-Matchbox</td>
<td>Online</td>
<td>1113</td>
<td>48%</td>
<td>44%</td>
<td>Clinton</td>
</tr>
<tr>
<td>18</td>
<td>11/1-3</td>
<td>Lucid/The Times-Picayune</td>
<td>Online</td>
<td>873</td>
<td>44%</td>
<td>39%</td>
<td>Clinton</td>
</tr>
<tr>
<td>19</td>
<td>11/1-3</td>
<td>Fox News</td>
<td>Live phone</td>
<td>1107</td>
<td>45%</td>
<td>43%</td>
<td>Clinton</td>
</tr>
<tr>
<td>20</td>
<td>11/1-3</td>
<td>McClatchy/Marist</td>
<td>Live phone</td>
<td>940</td>
<td>44%</td>
<td>43%</td>
<td>Clinton</td>
</tr>
</tbody>
</table>

None of the polls provided the error of margin at any confidence level.
I.3 What students are required to do: 
(1) For each of 20 polls (do with Excel): 
   a) For Hillary Clinton: 
      (i) Calculate the sample standard deviation of supporting proportion; 
      (ii) Calculate the error of margin of the sample with 85%, 90%, 95%, 99% confidence 
           level respectively; 
      (iii) Calculate the confidence interval for the supporting proportion in population with 
           85%, 90%, 95%, 99% confidence level respectively. 
   b) For Donald Trump: 
      (i) Calculate the sample standard deviation of supporting proportion; 
      (ii) Calculate the error of margin of the sample with 85%, 90%, 95%, 99% confidence 
           level respectively; 
      (iii) Calculate the confidence interval for the supporting proportion in population with 
           85%, 90%, 95%, 99% confidence level respectively. 
   c) Based on the results in a) and b), tell whether we can conclude, with 85%, 90%, 95%, 
      99% confidence level respectively, that supporting rate of Clinton is higher than supporting rate 
      of Trump in the nation. 

(2) Count how many of the 20 polls led to the statistical conclusion that Clinton was winning, 
    with 85%, 90%, 95%, 99% confidence level respectively. 

(3) Briefly discuss the following two questions: 
    a) Based the above analyses on the 20 polls, how confident you would say that Clinton 
       would win the election, assuming that the samples in all polls are random and valid? 
    b) What are possible factors which may affect the validness and randomness of the 
       samples in the polls? 

II. Analyses and Discussions 

Table 2 shows the calculation results of the errors of margin and confidence intervals with 95% 
confidence level of the 20 polls regarding Hilary Clinton’s supporting rate in the population 
which is the whole country: 

<table>
<thead>
<tr>
<th>#</th>
<th>Sample size, n</th>
<th>Clinton sample support %</th>
<th>95% E, error margin, Clinton</th>
<th>Low of 95% Confidence Interval, Clinton</th>
<th>High of 95% Confidence Interval, Clinton</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3669</td>
<td>45%</td>
<td>0.0161029</td>
<td>43.39%</td>
<td>46.61%</td>
</tr>
<tr>
<td>2</td>
<td>1107</td>
<td>41%</td>
<td>0.0290047</td>
<td>38.10%</td>
<td>43.90%</td>
</tr>
<tr>
<td>3</td>
<td>940</td>
<td>45%</td>
<td>0.0318443</td>
<td>41.82%</td>
<td>48.18%</td>
</tr>
<tr>
<td>4</td>
<td>799</td>
<td>46%</td>
<td>0.0346106</td>
<td>42.54%</td>
<td>49.46%</td>
</tr>
</tbody>
</table>
Table 3 shows the calculation results of errors of margin and confidence intervals with 95% confidence level of the 20 polls regarding Donald Trump’s supporting rate in the population which is the whole country.

Table 3. Errors of margin and confidence intervals (95%) for Trump

<table>
<thead>
<tr>
<th>#</th>
<th>Sample size, n</th>
<th>Trump sample support %</th>
<th>95% E, error margin, Trump</th>
<th>Low of 95% Confidence Interval, Trump</th>
<th>High of 95% Confidence Interval, Trump</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>3669</td>
<td>41%</td>
<td>0.01592</td>
<td>39.41%</td>
<td>42.59%</td>
</tr>
<tr>
<td>2</td>
<td>1107</td>
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<td>0.029196</td>
<td>40.08%</td>
<td>45.92%</td>
</tr>
<tr>
<td>3</td>
<td>940</td>
<td>41%</td>
<td>0.031482</td>
<td>37.85%</td>
<td>44.15%</td>
</tr>
<tr>
<td>4</td>
<td>799</td>
<td>43%</td>
<td>0.03438</td>
<td>39.56%</td>
<td>46.44%</td>
</tr>
<tr>
<td>5</td>
<td>931</td>
<td>40%</td>
<td>0.03151</td>
<td>36.85%</td>
<td>43.15%</td>
</tr>
<tr>
<td>6</td>
<td>1295</td>
<td>44%</td>
<td>0.027061</td>
<td>41.29%</td>
<td>46.71%</td>
</tr>
<tr>
<td>7</td>
<td>748</td>
<td>44%</td>
<td>0.03563</td>
<td>40.44%</td>
<td>47.56%</td>
</tr>
<tr>
<td>8</td>
<td>2220</td>
<td>43%</td>
<td>0.020605</td>
<td>40.94%</td>
<td>45.06%</td>
</tr>
<tr>
<td>9</td>
<td>1426</td>
<td>43%</td>
<td>0.025718</td>
<td>40.43%</td>
<td>45.57%</td>
</tr>
<tr>
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<td>70194</td>
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<td>0.003639</td>
<td>40.64%</td>
<td>41.36%</td>
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<td>11</td>
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<td>43%</td>
<td>0.025074</td>
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<td>45.51%</td>
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<tr>
<td>12</td>
<td>2195</td>
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<td>36.96%</td>
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<tr>
<td>13</td>
<td>1625</td>
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<td>37.32%</td>
<td>42.68%</td>
</tr>
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<td>1009</td>
<td>44%</td>
<td>0.030665</td>
<td>40.93%</td>
<td>47.07%</td>
</tr>
</tbody>
</table>
Hypothesis testing is then carried out by comparing confidence intervals of Clinton and Trump for each of the twenty polls.

The **null hypothesis** is: In the population of the whole country, supporting rate of Clinton is same as supporting rate of Trump.

The null hypothesis is rejected if and only if the confidence interval of Clinton does not overlap the confidence interval of Trump in a poll. The hypothesis testing results with 95% confidence level are given in Table 4.

| #  | Clinton sample support % | Trump sample support % | Low of 95% Confidence Interval, Clinton | High of 95% Confidence Interval, Clinton | Low of 95% Confidence Interval, Trump | High of 95% Confidence Interval, Trump | Can reject null hypothesis?
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
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<td>1</td>
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<td>41%</td>
<td>43.4%</td>
<td>46.6%</td>
<td>39.4%</td>
<td>42.6%</td>
<td>Yes</td>
</tr>
<tr>
<td>2</td>
<td>41%</td>
<td>43%</td>
<td>38.1%</td>
<td>43.9%</td>
<td>40.1%</td>
<td>45.9%</td>
<td>No</td>
</tr>
<tr>
<td>3</td>
<td>45%</td>
<td>41%</td>
<td>41.8%</td>
<td>48.2%</td>
<td>37.9%</td>
<td>44.1%</td>
<td>No</td>
</tr>
<tr>
<td>4</td>
<td>46%</td>
<td>43%</td>
<td>42.5%</td>
<td>49.5%</td>
<td>39.6%</td>
<td>46.4%</td>
<td>No</td>
</tr>
<tr>
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<tr>
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<td>42%</td>
<td>42.5%</td>
<td>47.5%</td>
<td>39.5%</td>
<td>44.5%</td>
<td>No</td>
</tr>
<tr>
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<td>44%</td>
<td>40%</td>
<td>41.3%</td>
<td>46.7%</td>
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<td>42.7%</td>
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</tr>
<tr>
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<td>44%</td>
<td>44.9%</td>
<td>51.1%</td>
<td>40.9%</td>
<td>47.1%</td>
<td>No</td>
</tr>
<tr>
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<td>44%</td>
<td>45.1%</td>
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<td>47.2%</td>
<td>39.8%</td>
<td>46.2%</td>
<td>No</td>
</tr>
</tbody>
</table>

Table 5 shows the results of hypothesis testing on the null hypothesis on the twenty polls with four different confidence levels, 85%, 90%, 95%, and 99%.
Table 5. Summary of the results of hypothesis testing at four confidence levels

<table>
<thead>
<tr>
<th>#</th>
<th>Clinton sample support %</th>
<th>Trump sample support %</th>
<th>Can reject null hypothesis with 85% confidence?</th>
<th>Can reject null hypothesis with 90% confidence?</th>
<th>Can reject null hypothesis with 95% confidence?</th>
<th>Can reject null hypothesis with 99% confidence?</th>
</tr>
</thead>
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<td><strong>90%</strong></td>
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We can see that, of the twenty, only two polls can reject the null hypothesis that Clinton’s supporting rate in the whole country is same as that of Trump with 95% confidence, and only four can reject the null hypothesis with 90% confidence, even though 19 out of 20 polls showed that Clinton’s supporting rate was higher, or much higher, than Trump’s supporting rate. The election result is thus not a “surprise” in the sense of statistics based on the polls, as the above analyses revealed.

The twenty polls showing to the public did not tell the errors of margins and confidence intervals. They did not provide complete information statistically. On the other hand, many people had a myth that a sample should reflect the population exactly. The incomplete information and misunderstanding of the results of polls caused a “surprise” at the election result.
III. What Students Have Learned from this Case Study

This case was given to students just a few days after the Nov. 8 election. Students showed high interests in doing it. They were enthusiastic in finding out why the election outcome was opposite to most polls of media by using their own knowledge just learned.

Technically, by doing this case, students have reviewed their skills of calculating standard deviations of samples, errors of margins, and confidence intervals with various confidence levels, and draw the statistical conclusion by themselves.

Conceptually, this case study has illustrated the difference between a sample and the population from which the sample is drawn, and meanings of error of margin and confidence interval. Particularly,
(a) Statistics is to investigate some characters of a population by using a sample from it.
(b) There are always errors when we use a sample to tell what its population is like, even though the sample is perfectly random and its results are accurately counted.
(c) In general, the larger the sample size, the more accurate the sample reflects the population.
(d) Confidence interval with higher confidence is larger than that with lower confidence.

Students also discussed factors that might have affected the validness of a sample, and some other related issues. For example, online polls might have excluded aged people, poor people, and people who were busy with two jobs without having time to surf online. And what if the twenty polls were viewed as a “super-poll”? …

References

Navigating Multiple SAP Implementations at a Major Food Processing Company

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This case study examines the trials and tribulations of a series of SAP implementations at a major food processing company beginning in 2005. After going through a series of mergers and acquisitions from the 1980’s and into the 2000’s, the organization was faced with managing a multitude of information systems running in different plants and subsidiaries throughout its supply chain. The case examines the implementation starting in 2004, when the main office was still running an antiquated custom-built legacy system which could no longer support the company’s inventory and accounts receivables systems. In 2005, the first implementation project began when SAP was selected to manage its order-to-cash process. Soon afterwards, in 2007, two major business units of the organization were merged in an effort to strategically streamline its operations. At the same time this newly formed business unit went through a full “wall-to-wall” SAP implementation, which involved consolidating all major business functions on one system. Soon after completing the consolidation in 2014, the company went through legal restructuring, consolidating multiple separate entities into four major business units. The decision was made to develop company-wide data definition, and require that all business units convert their operations onto a single enterprise platform. This triggered a third SAP implementation. At the same time SAP AG was rolling out SAP system operating from in-memory database (SAP HANA). Therefore, the last SAP re-implementation is also accompanied by a major update in the enterprise software.

The case is intended for use in a management information systems class, or in strategic management class. It is intended to emphasize and illustrate the following learning points:

- Information technology strategy must be aligned with and driven by the corporate strategy
- For the implementation to be successful, an appropriate IT governance structure should be established
- Oftentimes enterprise software installation involves integration with third-party software packages, which require substantial EAI efforts
- Enterprise software installation virtually always requires certain degree of configuration and custom programming, because very rarely standard software configuration fits the company’s business model
CORPORATE SOCIAL RESPONSIBILITY AS A CORPORATE STRATEGY, DO INVESTORS BENEFIT?

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Abstract

Viewing engagement in Corporate Social Responsible (CSR) activity as a purposeful business strategy to maximize evaluation, the author employed the Reputation Institute's 2015 Global CSR RepTrak scorings of the most reputable companies as ranked by the general public across 15 countries as independent variable hypothetically related to Market Value Added (MVA). The current study utilizes global 2015 data and employs balance sheet data (investor equity) to explore the possible benefit to investors from a strong CSR strategy.

The MVA of each corporation was calculated and regressed on their reputation scores, testing if perceived levels of CSR are associated with a premium added by the market over and beyond the value of the investors investment (MVA). The purpose of the study is to determine if high expenditures within a CSR corporate strategy yields economic benefit to investors.

To date, conclusive information on the market effect of CSR expenditures has been elusive. Since CSR became a managerial topic in the early 1950’s, only half of studies in the literature found some weak relationship but most studied the relationship between CSR and profitability. Differentially, the present study examines the relationship between CSR and market capitalization over investment, hence examining the possible effect on premium equity evaluation related to CSR.

The present study findings reject the hypothesis of a statistically significant relationship between CSR and MVA. Although stockholders certainly purchase the products of firms they frequent and enjoy, we may conclude the equity market is indifferent to CSR activity and the expenditure costs of CSR activities do not translate to higher evaluations.

Keywords: Corporate Social Responsibility, Market Value, Market Value Added, Corporate Strategy, Brand Management
Introduction

Reputation, a durable and persuasive construct modulating and magnifying perception of information, hypothetically strengthens the demand for the stock as well as market acceptance for the product (at a higher price). It follows that reputation also enhances the difference between the market value of the firm and investors input. Do investors of Starbucks purchase stock merely for returns or do they invest because they believe the firm is overtly socially responsible? Do customers pay marginally higher prices for coffee products for the same reason? Do these actions produce higher profit margins, and higher evaluations?

The present study investigates the relationship of Market Value Added (MVA) associated with levels of corporate social responsibility (CSR). MVA is a concept developed by the consulting firm Stern & Stern in the 1990's wherein they echo Milton Freedman stating that senior executives should be focused on maximizing a firm's market value. One corporate strategy widely used is enhancing CSR expenditures to enhance reputation thereby theoretically enhancing the stock price. The question becomes, do these additional expenditures negate or enhance the demand for the stock? This line of questioning leads to a testable hypothesis;

Ha: Firms with higher scores of perceived Corporate Social Responsibility will exhibit higher levels of Market Value Added (MVA) to stockholders.

As about 48% of the U.S. public is active in purchasing stock or bonds and with strong social-media activity, wherein we may assume the public displays an awareness of their favorite company and brands. Here, it is assumed the public knows of and expects substantial CSR activity in their favorite firm's mission statement, reports and value-propositions. These issues are part of every celebrity CEOs promotions. Hence, the public knowingly frequents these companies producing not only higher sales revenue, volume purchase frequency, a lowered cost of capital, and a greater tendency to purchase equity. Such behavior would produce an increase in market value.

The Literature

The Corporate Social Responsibility literature is robust with at least 588 journal articles and 102 books (Aguinis & Glavas (2012:934). There continues an acceleration of academic and industrial interest in this subject area. The earliest studies were in the 1970's, i.e. Milton Moskowitz (1972) and Stanley Vance (1975). In 2010, Dacin, Dacin & Matear (39) outlined 37 studies merely defining the construct of CSR.

The definition of CSR has evolved over the last fifty years. Starting as a simple concept of charity, then it included volunteerism, then philanthropy was added. CSR has now grown to encompass local community issues, global issues, social issues, and local pollution concerns, but now includes the domain of environmental issues to most recently become defined as the “triple bottom line,” including the global natural environment and potential climate change as management’s domain of responsibility.

This construct expansion was denoted by Aquinas (2011: 855) and adopted by others (e.g., Rupp, 2011; Rupp, Williams, & Aguilera, 2010), wherein CSR is defined as, “context-specific organizational actions and policies that take into account stakeholders’ expectations and the
triple bottom line of economic, social, and environmental performance. “Currently, the expanded definition of CSR refers to policies and actions by management, such policies and actions are influenced and implemented by actors at all levels of analysis (e.g., institutional, organizational, and individual) and all stakeholders.

Discussion

The issue of CSR has always had a provocative component because of a diametric sourced from classical economic theory wherein the objective (and value) of a profit-driven firm should be absolutely opposed to any communal activity. On one pole is the rigid “firm-purpose view” of “shareholder wealth maximization” wherein management is answerable to only the owner-class. The other pole is the triple bottom line, an expanded concept of the firm where all stakeholder groups interests should be maximized in a multi-level paradigm encompassing the entire society and environment.

Milton Friedman (1970) is often quoted as representing the standard philosophy of Shareholder Wealth Maximization (SWM) containing no allowance for corporate philanthropy of any kind. Friedman stated, “There is one and only one social responsibility of business, to use its resources and engage in activities designed to increase its profits so long as it stays within the rules of the game, which is to say, engages in open and free competition without deception or fraud.” Concisely, within Friedman-SWM theory, the sole purpose of the firm is to create wealth for the stockholders following from the fact the firm is funded by stockholders. Friedman and many others adhere to the belief diversion of stockholder equity to any activity other than the purpose of the business is inappropriate and would directly reduce rates of return to stockholders, increase the risk of the future cash flows, and would necessarily require additional funding, and raise the cost of capital. All of these actions would reduce the firm's evaluation. Viewed within this paradigm, CSR reduces the value of the firm, diminishing returns to stockholders, and that in turn, would reduce the owner's ability to “perform good” within their communities. Further, Friedman-SWM notes corporate executives have no or little training in CSR evaluation or activity and the diversion of corporate assets (and labor time and effort) would, in a word, reduce the market value of the firm.

Drucker (1984:62) somewhat softened Friedman’s-SWM theory when he stated, “…but, the proper ‘social responsibility’ of business is to tame the dragon, that is to turn a social problem into an economic opportunity and economic benefit, into productive capacity, into human competence, into well-paid jobs, and into wealth.” Peter Drucker called for a scanning of the social needs “market” using the business organization as a tool to convert social problems into business opportunities, henceforth justifying profit-making in the CSR arena.

These views have become paramount as early as 2004. More than half of the Fortune 1000 companies issue corporate social responsibility (CSR) reports. Consumers, investors, and employee stakeholders are becoming increasingly aware of the mission and values of their favorite firms.

The literature leads us to look for higher valuations for high-level-CSR corporations. Within the literature, it is reported companies perceived to have a strong CSR commitment often have an increased ability to attract and retain employees (Turban & Greening: 1997), which leads to reduced turnover, recruitment, and training costs. It is noted in current research, firms may
benefit from socially responsible actions in terms of employee morale and productivity. (Soloman & Hansen: 1985). Aguinis & Glavas note a consistent finding regarding the institutional-level outcomes of CSR initiatives as an improvement in a firm’s reputation (Brammer & Pavelin, 2006; Fombrun & Shanley, 1990; Turban & Greening, 1997; Verschoor, 1998; Waddock & Graves, 1997b). A positive effect has been found, for example, on the part of consumers (Arora & Henderson, 2007; Sen & Bhattacharya, 2001), who respond to CSR through favorable evaluations of the firm and its products (Brown & Dacin, 1997; Ellen, Mohr, & Webb, 2000; Sen & Bhattacharya, 2001) as well as through increased loyalty (Maignan, Ferrell, & Hult, 1999) Aguinis & Glavas, 2012:940). Reductions in such expenditures should produce higher margins, and higher evaluations per dollar invested.

The issue of financial performance of high versus low CSR firms is well-noted in the literature. Margolis & Walsh (2003) note 122 published articles between 1971 and 2001 empirically examining the relationship between CSR and financial performance. Peloza (2009) reviewed 128 studies which analyzed the CSR-economic evaluation association. This fundamental question has yet to be resolved, wherein Surroca, Tribo & Waddock (2010) did not find a direct relationship between CSR and financial performance in a sample of 599 corporations in 28 countries. Aguinis & Glavas find a “small but positive relationship between CSR actions and policies and financial outcomes” (2013:943). Peloza (2009) reported of 128 studies that explored the CSR-Performance association, 59% found a positive relationship, 27% a mixed or neutral relationship, and 14% a negative relationship.

The actual relationship between perceived CSR and equity yields may be mitigated by research methodology, data sampling, longitudinal variation, operational definitions and errors in construct specification. However, Aguinis & Glavas, in their benchmark Journal of Management (2012:953-956) study, “What We Know and Don’t Know About Corporate Social Responsibility: A Review and Research Agenda” indicate there is an opportunity to contribute to this area of research. They note, “What is the impact of these generational differences on the types of CSR actions?” Hence, the present study recognizes a need for another investigation of the association between perceived CSR and investor's equity performance.

The Construct of Corporate Social Responsibility

Harvard’s Kennedy School Corporate Social Responsibility Initiative states, “We define corporate social responsibility strategically…it goes beyond philanthropy and compliance and addresses how companies manage their economic, social, and environmental impacts...in all key spheres of influence: the workplace, the marketplace, the supply chain, the community, and the public policy realm.” The term “corporate social responsibility” is often used interchangeably within; corporate responsibility, corporate citizenship, social enterprise, sustainability, sustainable development, triple-bottom line, corporate ethics, and in some cases corporate governance. Though these terms are different, they all point in the same direction: throughout the industrialized world and in many developing countries there has been a sharp increase in the social roles corporations are expected to play. Companies are facing new demands to engage in public-private partnerships and are under growing pressure to be accountable not only to shareholders, but to all stakeholders such as; employees, consumers, suppliers, local communities, policymakers, and society-at-large.
The Reputation Institute study found, “the general public tends to rate makers of beverages, consumer products, and computers substantially along social dimensions. The results indicate relative appreciation for those customer-facing sectors – and suggest favorable social perceptions for companies in these sectors.” The reputation for the service or product is difficult to separate from the reputation for socially positive actions. The Harris Interactive Quotient Survey outlines six dimensions that influence reputation; social responsibility, emotional appeal, financial performance, products and services, vision and leadership, and workplace environment.

**The Construct of Market Value Added (MVA)**\(^1,2\)

During the 1990's, the concept of MVA was promoted most heavily by Stern & Stewart, a New York based consulting firm. The firm's founders Joel Stern and Bennett Stewart became the foremost promoters for the metric. Their success spawned a whole host of imitators from other consulting firms, all of which were variants on the excess return measure.

In the process of applying this measure to real firms, Stern & Stewart found most executives did not make the decisions necessary to maximize shareholder wealth because they failed to consider the capital invested in the business and the cost of capital to shareholders. With consideration of capital investment, most corporations were under-producing yields and not returning sufficient returns to investors. In his important book, titled, *The Quest for Value*, Bennett Stewart outlines the use of MVA to maximize the value of the firm. Most U.S. corporate executives began to use the concept as a cornerstone in their strategic management.

Market Value added (MVA), is simply the difference between the current total market value of a company (market capitalization) and the value of capital contributed by investors. Capital invested could include both shareholders and bondholders, however the present study used just the capital invested by shareholders, as we focus on returns to them. Unlike Economic Value Added (EVA, a performance metric) MVA is instead a wealth metric, measuring the economic value a company has accumulated over time. As a company performs well over time, it will retain earnings. This will improve the book value of the company's shares, and investors will likely bid up the prices of those shares in expectation of future earnings, causing the company's market value to rise. As this occurs, the difference between the company's market value and the capital contributed by investors represents the excess value the market assigns to the company as a result of past operating successes. Hence, there should be a strong relationship between market capitalization and invested capital and CSR. For the current study, MVA was computed as the balance sheet items, common stock, added to retained earnings less any treasury stock repurchased. All data was derived from 2016 Yahoo/finance.

**Data**

The Reputation Institute produces the CSR RepTrak 100 report. The report ranks and scores the one hundred most reputable firms as indicated by the general public across 15 countries. The current study employed 2015 data. The report measures respondents view on the firm's; quality of product/services, level of innovation, quality of the workplace, strength and transparency of governance, community and citizenship, transparency and responsiveness of leadership, and financial performance. The Institute then summarizes the public's views on a firm's overall...
social behavior and social responsibility. The Reputation Institute states firms with higher CSR ranking produce better financial performance for investors. A sample of CSR rankings with 2016 MVA are presented in Table 1.

Table 1
Global Companies CSR Reputations and MVA
($b. USD) - Sample Data

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<th>Corporation</th>
<th>CSR Score</th>
<th>MVA $b.</th>
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<tr>
<td>Google (Alphabet)</td>
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<tr>
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<td>Volkswagen</td>
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Methodology

The Reputation Institute produces a ranked list of global companies ranked for perceived CSR based on their 2015 global study. Internationally, Google was found to have the highest perceived CSR with a score of 75.4, and UPS was scored lowest with a score of 63.97. These CSR score rankings were used as the independent variable and computed MVA was employed as the dependent variable within a linear regression.

Yahoo/finance database provided each firm's; common stock investment, preferred stock and retained earnings. The total stockholder's investment was calculated by adding the common stock to the retained earnings, any preferred stock and subtracting any treasury stock reported. Many of the larger firms have been purchasing their stock in recent years as the cost of borrowing has been very low. Debt was not included. MVA was computed by subtracting the total stockholder's investment from the current market capitalization.

Twenty-one corporations were eliminated from the study when; merger activity was detected, the firm was privately held, acquisitions occurred, or incomplete balance sheet data was found therein. The current study used N=79. Data from the full Table 1 are visualized in Graph 1 below.

Results

The regression of Market Value Added (MVA) on CSR score output yields an adjusted R square = 0.03 , $R^2 = 0.05$ , $F=3.74$ , $p=0.057$ , $df=78$). The results approached, but failed to reach significance of $p<0.05$ level and therefore, the alternative hypothesis is rejected. See Table 2. The current study fails to find a statistically significant relationship between the variables MVA and the Reputation Institutes 2015 Global CSR RepTrak 100 “reputation scoring” of CSR activities. Since the market value beyond equity investment were not found to be greater in any
firm with higher levels of CSR, we reject the alternative hypothesis as it is likely $B = 0$. We may conclude the cost of CSR expenditures are not reflected in market values.

Table 2
Regression ANOVA Analysis
(Independent Variable=CSR; Dependent Variable=MVA)

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Conclusions

The rejection of the alternate hypotheses, $H_a$, leads to acceptance of the null hypotheses indicating no detectable statistical relationship between the variables MVA and perceived CSR scores. We may conclude within the time of this study (2015-2016) society has not developed an enhanced appreciation for CSR expenditures and activities and differential market premiums exhibited by market investment activity were not found.

Importance to the Practitioner

These results inform and caution both investor's and corporate executives contemplating enhanced CSR expenditures. CSR expenditures and activities intended to be reflected as heightened stock prices resulting in rewards to stockholders may not result in higher stock evaluations. This is especially important as the purview of the CSR construct expands to global environmental issues including climate change thereby increasing potential future expenditures.

The triple bottom line now includes environmental CSR activities including carbon sequestering efforts. These carbon-neutral activities are high capital-intensities and have high expenditures, and are not likely reflected in enhanced stockholder return.

The current study does not propose that customers do not appreciate CSR activity, merely the cost of CSR may counteract any extra demand for equity, producing a wash negating any premium stock price.
The present study informs investors and the investment industry performing predictive fundamental analysis to be cautious in assuming enhanced returns for highly-visible CSR activities. Investing strategy should not expect higher equity evaluations with better CSR reputations in relation to firms with suspect reputations.

These results also inform entrepreneurs that the creation of enterprises with enhanced CSR mission-value statements may not necessarily lead to lower costs of capital and larger funding levels.

**Future Research**

It is possible CSR activity has become an accepted prerequisite to business operations and hence such expenditures are not differentiable to the market. Furthermore, the present study presents firms ranked high in CSR and therefore the data may not be statically noticeable. Hence future research should utilize data from both highly ranked and lower strata CSR firms. Data including firms with lower CSR rankings is difficult to source as publication of a low CSR may invoke legal liability. It is suggested an analysis of groups, one with high CSR and one with low CSR may show significant differences.

It appears that for the highest-CSR rated firms (taken as a class), the public is not willing to pay a premium stock price for the higher ranked firms. The author believes the present findings warrants further study for the important issue of employing Corporate Social Responsibility as a business strategy.

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HOW DO SELLER REVIEWS CULTIVATE CONSUMERS’ PERCEPTIONS OF TRUST, RISKS, AND UNCERTAINTY?

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Abstract — Seller reviews reveal consumers’ feelings about sellers’ services as well as their experiences with products. Aiming to examine the impact of seller reviews on consumers’ perceived uncertainty in e-commerce, a two-stage study was conducted from text mining to behavioral study. The goal of the text mining was to investigate the semantic patterns in the content of seller reviews. The continued behavioral study in the manner of quasi-experimental design extends the findings in text mining by measuring how this trust feeling impacts consumers’ perceptions. The findings in our study contribute to the literature from both theoretical and practical perspectives.

Keywords — Seller Reviews; Trust; Perceived Information Asymmetry; Perceived Seller Opportunism; Perceived Uncertainty

I. INTRODUCTION

The success of web-portal s such as Amazon and EBay well indicates the prevalence of virtual business. In contrast to brick-and-mortar businesses, the virtual shopping environment of online business essentially involves the existence of uncertainty. To overcome the difficulties incurred by this uncertainty, web designers and researchers have employed several means of improving the transparency of product information. Online reviews were created as one of the means and are broadly acknowledged for their richness of information. Several studies have verified the effectiveness of online reviews in assisting consumers’ purchasing experiences online. However, the richness of information in online reviews also indicates that uncovering useful information from them becomes a challenging job, especially when most of reviews are full of mixed comments, sentiments and evidence. To get a better understanding about the relationship between review comments and consumer behavior, many researchers have adopted text mining as their analytical tool of choice to uncover associated patterns.

Text mining has long been accepted as an effective automated or semi-automated process to retrieve information from unstructured textual documents [1]. Basically, text mining differs from regular data mining from two reasons: 1) it mainly analyzes text instead of numbers; 2) it needs highly-structured data [2]. Text mining is no longer considered an emerging technique as it has been broadly applied in many fields. Our study intends to use text mining techniques to uncover sentimental patterns in online reviews. However, while text mining excels in extracting information and uncovering structure from textual documents similar to many research methodologies, its ability to explain consumer behavior is very limited. On the other hand, behavioral studies which are used for validating and building theories lack the ability to uncover unknown patterns. Therefore, these two methods to some extent are good complements to each other. Consequently, we propose to integrate behavioral studies with text mining in this study to overcome the limitations of text mining as well as to contribute to theory development. Specifically, text mining is used to uncover semantic patterns—especially from the perspective of trust feelings—in consumer reviews of sellers and products, and our behavioral study is aimed at testing the findings from the text mining and checking for its impact on people’s behavior.

Our study contributes to the current literature in two ways. First, we apply text mining to extract consumer opinions concerning the perspective of trust feelings. There are some prior studies working on interpreting consumers’ voices in consumer reviews. However, most of them overemphasize the
importance of the sentimental characteristics of reviews. For example, some of the researchers cluster consumer reviews based on the subjectivity in review content, and this subjectivity is measured by the proportion of adjectives in the sentences [3]. Actually, in some cases, the viewpoints these reviews are taking should be judged based on the context of the arguments, especially in neutral reviews. In some neutral reviews reviewers did not mention many negative issues within the transactions considered in the reviews; instead, they wrote many compliments. However, when they occur, those negative words can more represent reviewers’ viewpoints than positive words, although the proportion of the negative words in the sentences may be low. As a supplement, it would be helpful to consider the semantic features in the statements of reviews.

Second, a survey-based study is conducted to measure the impact of the findings in text mining on people’s behavior. The semantic patterns uncovered in text mining can only tell us the main topics embraced in reviews; however, it remains obscure exactly how these semantic features in reviews reflect on peoples’ decision making. As mentioned in the beginning, consumer reviews were initially created to help consumers mitigate the uncertainty and risks involved in online transactions. The focal perceptions to investigate in this study are perceived uncertainty and risks, although there could be other perceptions such as purchase intention in the purchase decision making process. In the surveys, the reviews are manipulated based on the findings from our text mining, and the perceptions are measured by the instruments adopted from the existing literature.

The rest of our paper is organized as follows. In Section 2, the theoretical background underlying the study is introduced including both the theory and the methodology adopted. In Section 3, a content analysis is applied to uncover the semantic patterns in seller reviews from the perspective of trust. In Section 4, a survey-based study is implemented to measure the psychological effects of the findings in Section 5 on consumers’ perceptions. In Section 5, the related analyses of the hypothesis tests and model establishment are presented. The paper ends with a discussion of our findings and potential future work.

II. THEORETICAL BACKGROUND
A. Trust Belief in Seller Reviews

Trust is a prevalent factor under discussion in the field of consumer behavior [4-6]. Researchers find that the trust in online transactions can be enhanced with the presence of additional information such as third party seals or those of recommendation agents. Third party seals refer to the assurance provided by third-party certificating bodies such as banks, consumer unions or computer companies [6]. Kim et al. find that the presence of a third-party seal can enhance consumers’ trust of sellers [6]. Regarding recommendation agents (referring to the software agents for product recommendation based on elicited consumer preferences), Kumar and Benbasat maintain that providing recommendation agents in a website can enhance both the perceived usefulness and the social presence of that website [7]. Additionally, Xiao and Benbasat further point out that recommendation agents can support and improve consumers’ decisions when searching for and selecting products online by reducing the information overload and the complexity of online searches [8].

Some researchers have noticed the effect of trust elements embedded in consumer reviews. For example, Pavlou and Dimoka cluster the reviews in eBay into four categories in terms of trust—outstanding benevolence comments, abysmal benevolence comments, outstanding credibility comments, and abysmal credibility comments [9]. They point out that the content of consumer reviews has a certain ability to affect the price premiums of products. This finding confirms our assumption in this study that seller reviews embrace the information that reflects reviewers’ trust in sellers. Studies show that when it is possible to transfer trust from one entity to another, trust transference is one of the efficient
strategies with which to develop trust. When a consumer trusts a well-known web portal such as eBay or Amazon, he would tend to trust sellers affiliated with the portal based solely on the reputation of the web portal [5]. We assume that if a consumer trusts a seller, he would trust this seller’s products as well. Consequently, we believe that the trust feeling expressed in seller reviews has the ability to impact consumers’ impressions of sellers and the products they are selling and the extent to which these readers decide to trust the discussed sellers is determined by how much trust feeling they sense from the reviews. This premise provides the rationale for the current study.

B. Principal Agent Theory

One of the goals of this study is to investigate how seller reviews impact consumer decision making. The nature of e-commerce causes uncertainty between buyers and sellers. Principal agent theory, which deals with this type of uncertainty, is another fundamental theory utilized in this study. Principal agent theory was initially created to explain the dilemma in principal-agent relationships. In the principal-agent dilemma, principals hire agents to pursue their interests. For example, stockholders hire a CEO to operate a company. The stockholders in the example are the principals, and the CEO is the agent. The agent is requested to perform on behalf of the principals; however, there may sometimes be a conflict of interest between the two parties. Both of them are assumed to be self-interested economic entities, which mean that agents may undertake some acts to achieve their own interests while sacrificing the principals’ interests. The theory indicates that the temporal separation between the goal integrity of the principals and agents causes the existence of hidden information and hidden actions in the principal-agent relationship which produces uncertainty [10-13].

Principal agent theory has been used to explain buyer-seller relationships [11]. If sellers are treated as agents and buyers as principals and the final transaction is viewed as a contract between the buyer and the seller, then there exist similar problems of hidden information and hidden actions due to the spatial and temporal separation involved in online purchasing. Sellers are assumed to know more than perspective buyers about the quality of the products and the execution of the related transactions. The related uncertainty can prevent buyers from purchasing products and engaging in transactions with the sellers.

The principal agent theory also explains the relationship between risk and uncertainty in this context. For example, on the basis of this theory, Pavlou et al. have proposed four potential risks in online transactions related to consumers’ risk perceptions: perceived information asymmetry, fear of seller opportunism, information privacy concerns and information security concerns [11]. They also find that, in the context of online book purchasing and prescription filling, the product diagnosticity, website informativeness, and the trust and social presence of a web portal can help mitigate associated risks and uncertainty. All these indicate that principal agent theory is capable and suitable of explaining the risk-uncertainty problem in the context of e-commerce.

C. Hypotheses Regarding Perceived Risk

Perceived risk is one of the broadly discussed factors in the literature of e-commerce. Risks can be measured in several ways. Sometimes, researchers simply measure the perceived risk in general. For instance, these researchers ask the subjects directly about the extent to which the subjects think the transaction is risky, is likely to cause trouble in the future, or is associated with a good chance of mistakes the decision maker might make [14]. Sometimes, researchers take a deeper look at these risks with consideration of potential resource expenditures. For example, some of them measure risks in the format of financial risks, time risks, performance risks and
social risks [14, 15]. The measure of perceived risk can also vary as conditions change.

As stated by Pavlou et al., in principal agent theory, risks are assumed to derive from sellers’ hidden information and hidden actions [11]. Hidden information technically refers to occasions when sellers intentionally hide information about products and transactions. Hidden action is when sellers break their implicit promises by sending low quality or counterfeit products to consumers. Using the principal agent theory, researchers have proposed four types of risks in their studies—perceived information asymmetry, fear of seller opportunism, information privacy concerns and information security concerns. By definition, perceived information asymmetry is equivalent to the risk of hidden information since both result from the asymmetrical distribution of information between buyers and sellers. Fear of seller opportunism corresponds to the risk of hidden actions resulting from activities such as quality cheating, contract default, failure to acknowledge return or refund and so on. Meanwhile, information privacy concerns and information security concerns are inherently relevant to the risks related to the environment of websites [11]. Privacy and security concerns, while important and interesting are not relevant to our focal questions. Therefore, we have removed from them from our consideration and have simply used the instruments in Pavlou et al.’s study to measure perceived information asymmetry and fears of seller opportunism. Formally stated, the relevant hypotheses are as follows:

H1: Perceived benevolence has a negative impact on perceived information asymmetry.

H2: Perceived benevolence has a negative impact on fears of seller opportunism.

H3: Perceived competence has a negative impact on perceived information asymmetry.

H4: Perceived competence has a negative impact on fears of seller opportunism.

H5: Perceived integrity has a negative impact on perceived information asymmetry.

H6: Perceived integrity has a negative impact on fears of seller opportunism.

D. Hypotheses Regarding Perceived Uncertainty

Uncertainty has been viewed as a barrier to e-commerce adoption [16]. To foster the development of e-commerce, many studies have been done to investigate various approaches to reduce this uncertainty in online transactions. For instance, Gregg and Waleczak have discovered that increasing the quality of e-images can reduce both the uncertainty and perceived risks involved in online transactions [17]. Weathers et al. find that information vividness also has such an effect on uncertainty [18]. In the context of consumer reviews, Weathers et al. additionally find that the reviews written by third parties are more effective at reducing uncertainty and enhancing information credibility with regard to search products, and product reviews provided by retailers are more effective at lowering uncertainty regarding experience products [18]. Here products such as MP3 players, music CDs, and PC video games, are viewed as experience products and products such as cell phones, digital cameras, and Laser printers are viewed as search products [19]. Compared to experience products, which are typically rated subjectively, the quality of search products is easier to evaluate objectively.

There is some evidence that trust mitigates uncertainty. For instance, Gefen finds both knowledge-based familiarity and trust can help reduce the uncertainty and simplify the buyer-seller relationship in online transactions [20]. Kim et al. also claim that consumers’ trust can help reduce their perception of risk and foster their purchase intentions [6]. On the basis of principal agent theory, Pavlou et al. proposed that four factors—trust, website informativeness, product diagnosticity and social presence—might help mitigate the uncertainty [11]. With the empirical tests of online book purchasing and online prescription filling their hypotheses are validated. With a comprehensive understanding of the findings in the literature, the rationale in our study is
that trust has an effect on mitigating uncertainty and this relationship is mediated by perceived risk. Therefore, we hypothesize that

H7: Perceived information asymmetry has a positive impact on perceived uncertainty.

H8: Fear of seller opportunism has a positive impact on perceived uncertainty.

Overall, the proposed measurement model, incorporating all the hypotheses proposed earlier, is presented in Figure 1.

III. CONTENT ANALYSIS
A. Data Collection in Content Analysis

The objective of implementing text mining in this study is simply to uncover the structure of the collection of seller reviews. Specifically, we are interested in examining how much information related to trust belief in sellers is incorporated in seller reviews and what words are used to express this trust belief. All the seller reviews were real and collected from ebay.com. The format of reviews on EBay varies slightly from other portals. First, the length of the reviews is specified. Other web portals, such as Amazon, grant consumers flexibility in the length of their reviews. In contrast, eBay only allows consumers 80 characters for each review; this is beneficial to our study because the opinions are condensed and expressed in an efficient way. eBay reviews differ in a second way: the reviews are anchored by a 3-point scaling system—positive, neutral, and negative. Normally, reviews are measured on a 5-point scale—extremely dislike, dislike, neutral, like, and extremely like. EBay’s 3-point scale is preferable for our study because it lessens the complexity of review content. Our past studies show that the differences between 4-star and 5-star reviews and 1-star and 2-star reviews are not very explicit [21]. Therefore, the reviews from EBay are the best for our study.

All of the reviews were manually collected from ebay.com. To increase the generalizability of reviews, we intentionally collected the reviews from different sellers. The merchandise these sellers market includes shoes, clothes, CDs, collectables, and small furniture. To avoid the one-sidedness caused by the unique performance of one specific seller, we collected a maximum of only 10 reviews from each seller. In the end, we amassed 500 reviews in each of the three categories of reviews—positive, neutral, and negative. With the focus of this study on sellers and not products, 500 reviews in each category reveal sufficient information about the sellers’ performance in transactions.

B. The Findings from Text Mining

After processing the document, three lists of words were identified respectively for positive, neutral, and negative reviews. In the tables, ‘in document’ means the number of documents containing that term, and ‘total’ means the overall frequency with which that term appears in all the documents. Although the wordlists have been shortened by our methods such as removing stop words and stemming, there are still some synonyms which cannot be automatically recognized by the system. Therefore, we decided to slightly adjust the wordlists manually by eliminating obviously synonymous words, for example, the words such as ‘ebayer’ and ‘seller’ or ‘ship’ and ‘deliver’. Some reviewers prefer to say ‘Good ebayer’ instead of ‘Good seller’, but obviously the ebayer in the review refers to the seller in the transaction. Sometimes reviews say ‘fast delivery’ instead of ‘fast shipping’. For the purposes of this study, the word ‘delivery’ is
considered equivalent to ‘shipping’. In some reviews, reviewers specify the name of the products they have bought, and product type is not our concern. Therefore, all the product names appearing in the reviews, such as ‘phone’ or ‘shoe’, were uniformly converted to ‘product’. Another type of transformation was to break duplicated phrases down into their root terms. Since terms with no more than 3 words are allowed, some phrases in the wordlists just represent the duplicated information as their root words do. For example, ‘fast_ship_thank’ literally means ‘fast shipping’ and ‘thank you’, which have already been included in the wordlist, so there is no reason to keep them in the wordlists.

Consistent with the common understanding, most of the positive reviews are compliments from prior consumers. The major ideas in positive reviews include the following points:

- the seller is great;
- the consumer thanks the seller;
- the shipping was fast/quick;
- the product/item is good/perfect and/or as advertised/described.

In contrast to positive reviews, most of the comments in negative reviews are complaints from prior consumers. The topics of negative reviews ranged from poor service to poor quality of the products. In summary, the main ideas in negative reviews include the following points:

- the buyer did not receive the purchased item and has been waiting for a while;
- the item is bad/horrible;
- the item sent was wrong or not as described/pictured;
- the item was not refunded on time and/or a high fee was charged for refunding;
- the order was cancelled due to shortage in stock;
- the seller was hard to communicate with and/or the service was poor.

Unlike either positive reviews or negative reviews, the emotion in neutral reviews is more complex. Overall, neutral reviews represent a negative attitude toward the transaction. But this kind of dissatisfied feeling is accompanied by a certain level of affirmative attitude toward the transaction. Therefore, neutral reviews have both positive comments and negative comments as follows:

- the item was shipped quickly;
- the item was shipped slowly and arrived later than expected;
- the item was good/fine;
- the item was not good and does not work;
- the item was not as described/pictured and the buyer had to refund/return it;
- the order was cancelled due to shortage of stock;
- the product looks cheap and the quality of the product looks poor;
- the package of the product was broken.

C. How is the Trust Feeling Revealed by Reviews?

As broadly discussed in the literature of trust, three antecedents—competence, benevolence and integrity—shape trust [22]. Competence is defined to be the belief that online sellers have the ability to accomplish what they promised; benevolence is the belief that online sellers care about consumer benefits and act in consumers’ interest; integrity is the belief that online seller will not take any opportunity to impair consumers’ benefits [11, 23].

As discussed earlier, the main topics covered in seller reviews include: 1) shipping, 2) overall assessment of sellers, 3) orders fulfilled, 4) after-sale service, 5) product return, 6) product quality and so on. Comparing these with the definition of the three antecedents of trust, we identified words reflecting sellers ‘attitudes, such as ‘easy to communicate with’ or ‘can never get in touch with the seller’ as being related to seller benevolence; words reflecting sellers’ ability to fulfill the purchasing agreement, such as ‘arrived earlier than expected’ or ‘well packed’, are related to sellers’ ability; and words such as ‘item as described’ or ‘pre owned: useless’, are related to seller integrity. As such, the majority of the seller reviews
can be theoretically classified based on the trust belief embedded in them.

IV. SURVEY ADMINISTRATION

A. Experiment Design

The content analysis discussed earlier reveals both that trust belief is a critical component of seller reviews, and that it is reasonable to categorize seller reviews based on the three antecedents of trust belief. To continue the study, we decided to perform a survey-based study to measure the impact of trust feelings on consumers’ decision making, especially perceived risk and perceived uncertainty. A 2x2x2 quasi-experiment, as illustrated in Table 1, was designed in the study. Consequently, eight versions of online surveys posted on Qualtrics.com were created. Qualtrics is a web-based survey software that enables users to develop and collect responses to surveys. All the information used in this part of the experiment was adopted and adapted from eBay. The reviews were initially written by the consumers of a real seller of electronic products on eBay. The surveys were emailed to around 450 undergraduate students in the business school of a mid-western university in the US. All the instruments used in the survey were adopted and adapted from previous research assessed on a five-point scale anchored at 1=strongly disagree, 3=neutral and 5=strongly agree.

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<td>Positive Integrity</td>
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<td>Version3</td>
<td>Positive Benevolence + Negative Competence +</td>
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<td>Positive Integrity</td>
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<td>Version4</td>
<td>Negative Benevolence + Negative Competence +</td>
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<td>Positive Integrity</td>
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<td>Version5</td>
<td>Positive Benevolence + Positive Competence +</td>
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<tr>
<td></td>
<td>Negative Integrity</td>
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<td>Version6</td>
<td>Negative Benevolence + Positive Competence +</td>
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In each survey, the subjects were requested to read four reviews of the same category as designed in Table 1. However, the reality is that the border of these three antecedents of trust in seller reviews is not explicit. In most reviews, the information on these three antecedents is entangling with each other. However, due to the reasons mentioned above, it is inappropriate to directly use the seller reviews from eBay. To control the effect of seller reviews and ensure that the reviews in the experiment functions as intended, we fabricated several fake reviews deriving from real ones. We looked for three individual reviews and ensured that at least one aspect of trust had been discussed in each review, and then combined these three reviews into a single review. In such a way, we ensure that every review in the experiments embraces complete information of prior customers’ trust.

B. Data Collection

392 responses were received in the survey. Several steps were necessary to clean up the data: 1) Delete incomplete responses (less than 20% completion rate). 13 incomplete responses were deleted, leaving 379 responses. 2) Delete non-first-time responses. The participants in the experiment were simultaneously recruited from several classes in a business school. To avoid duplicate responses, a question was intentionally asked at the end of each survey to check for the uniqueness of that response. In this step, 20 non-first-time responses were deleted, with 359 responses remaining. 3) Delete the responses with strong evidence showing the participant’s lack of attention on the survey. The participants were intentionally requested to choose “strongly agree” or “strongly disagree” in three questions to check that the
participants at least carefully read the questions in the survey. 141 responses indicated a lack of attention to the survey questions and were deleted. After deleting responses in these three areas, 218 valid responses remained in the study.

C. Measurement Validation
SmartPLS 1 for measurement validation and testing the structure model is adopted. We measured reliability which represents composite reliability. Composite reliabilities of all principal constructs are considered adequate since they exceed 0.8. Convergent and discriminant validity are tested as follows [11]: 1) all AVEs are greater than 0.50, suggesting that the variances explained by constructs are much higher than the error variances; 2) the square roots of AVEs are larger than the cross-correlations of the constructs; 3) all the cross-correlations of the constructs are lower than 0.90, which means that the constructs are distinct from each other. Also an excellent cross loading matrix suggests adequate convergent and discriminant validity.

V. DATA ANALYSIS
A. How do the three antecedents of trust constitute the overall trust?

![Diagram of the Structural Model on Trust]

As illustrated in Figure 2, the loadings of the instruments on the three antecedents of trust further indicate a good convergent validity of the measurement in the study. As mentioned earlier, the overall trust feeling is simply measured by one question — “to what extent do you think this seller is trustworthy?” As expected, the three antecedents of trust can well represent the overall trust by explaining 71.2% of the variation in the instrument of overall trust, and the significance of the paths from the antecedents to trust further prove it. Unique to the context of seller reviews, the path coefficients of the three antecedents to trust indicate not all the antecedents are equally important in forming the trust. The magnitude of the standardized path coefficients shows that perceived integrity has the strongest impact (0.604), perceived benevolence is the second (0.227), and perceived competence is the least (0.074). This also indicates that, although perceived benevolence and integrity are highly correlated, they are still distinct from each other.

B. Testing the Structural Model
A structural model as proposed earlier was run to test the hypotheses. The model indicates that both perceived information asymmetry (significant at 0.10) and the fears of seller opportunism (significant at 0.10) are good predictors of perceived uncertainty, explaining around 30% of the variability of perceived uncertainty. However, based on the magnitude of the standardized path coefficients, the fears of seller opportunism (0.524) have a stronger impact on perceived uncertainty than perceived asymmetry (0.141), suggesting that, in the context of seller reviews, consumers worry more about the possibility of sellers’ hidden actions than hidden information. As for the impact of trust from prior consumers, the model indicates that the trust feeling embedded in the seller reviews has no impact on people’s concerns about potential hidden information for the following two reasons: 1) none of the paths from the antecedents of trust to perceived information asymmetry is significant; 2) the variance of perceived information asymmetry explained by trust is very low, around

In contrast, the impact of trust in seller reviews on consumers’ fears of seller opportunism is very obvious. First, the paths from perceived competence (-0.153) and perceived integrity (-0.512) to the fears of seller opportunism are significant at 0.01. Second, these three antecedents of trust can explain 33.8% of the variance in fears of seller opportunism. The standardized path coefficients further suggest that only the information on sellers’ integrity and competence, especially integrity, in the seller reviews has the ability to lessen consumers’ concerns about sellers’ potential hidden actions. Consumers do not appear to care about sellers’ benevolence, although they can differentiate the change in the content regarding benevolence as suggested by the findings in the previous session.

Figure 13. Coefficients and R Squares for the Research Model

VI. Conclusion

This study measured the effect of seller reviews from the trust-construction perspective. It was assumed that seller reviews semantically embody prior consumers’ trust belief in sellers, and this trust belief can impact subsequent consumers in future transactions. The results in text mining validate the first half of the assumption. Although different reviews have different focuses in content, for example, positive reviews focusing more on the compliments of sellers’ good performance and negative reviews focusing more on the complaints of sellers’ bad performance in transactions, it is still reasonable to adopt the three antecedents of trust to read the voice in seller reviews. The text mining additionally uncovers the semantic structure in seller reviews and paves the road for the subsequent behavioral study.

The main objective of the behavioral study is to test the second part of the aforementioned assumption—how do seller reviews impact consumers? The focal perceptions of interest are the risks and uncertainty in online transactions. There are several expected findings as well as several unexpected ones. The risks in online transactions were measured in the format of information asymmetry (hidden information) and seller opportunism (hidden actions) based on the principal agent theory. Consistent with the theory, the uncertainty in online transactions is significantly composed of concerns about the seller’s potential hidden information and hidden actions. However, compared to seller opportunism, the concern about information asymmetry is negligible, which is understandable. With easy access to the internet, there is very little about the products that they do not know, so hidden information is no longer a concern. On the contrary, consumers worry more about the performance of sellers.

The behavioral study additionally shows that, although readers can correctly sense the feelings relevant to benevolence and competence in the reviews, the information on benevolence does not affect readers’ perceptions of either risk or uncertainty at all. As for integrity, readers’ perception does not particularly change because of content. No matter whether the information on sellers’ integrity is positive or negative, readers’ perception remains negative. The path coefficients in the structural model confirm this finding. Compared to perceived competence, perceived integrity has a much stronger effect on lessening perceived risk. Perceived benevolence becomes irrelevant. A MANOVA additionally shows that, to differentiate sellers’
integrity based on seller reviews, sellers’ competence should be considered simultaneously.

REFERENCE


There’s an App for That? Perspectives from the Public Sector

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ABSTRACT

This study examines mobile apps as a service provided through mobile government (m-government). Mobile apps are more typically associated with non-government businesses. The primary research question motivating this study is how are governments facilitating user engagement via mobile apps? This is a work-in-progress paper, with implications for both government agencies, and app developers.

KEYWORDS: M-government, consumer, citizen, user engagement

INTRODUCTION

Initial technology adoption is usually the first indication that a user intends to use a product. Once the initial acquisition of the product occurs, the user must then continue to actively engage with the product for there to be any perceived value. In the specific case of mobile devices, a recent empirical study illustrated that user engagement goes beyond adoption, and is strongly and positively related to user perceived value, user satisfaction and the user’s intention to continue to engage with the mobile device (Kim, Kim, & Wachter, 2013). A high level of engagement can lead to a perpetual state of user interaction with mobile devices.

As individuals make mobility an important part of their daily lives, governments have also begun to recognize that shift and are making attempts to respond to it. The consumer of information technology (IT) products is thus acting as a change agent in both the business and government arenas. This change influence that the consumer and their IT devices bring to the work environment is the heart of the phenomenon referred to as the “consumerization of IT”. The conventional view of the consumerization of IT is that individual consumers, most of who are also employed in private and public sector organizations were disrupting the work environment by bringing their own personal devices to work with them (Boomer, 2013). The consumerization of IT is now part of the public sector conversation, where individual consumers, who are also defined as citizens in the public domain are disrupting government services, with expectations that they can use personal devices for interaction with government agencies.

To expand on the above concepts, the paper proceeds in the following manner. In the literature review, I define m-government and provide specific examples of how it facilitates citizen interaction in a global context. After this I present a brief theoretical discussion exploring the dynamics of user engagement in the m-government domain. The overview of a research methodology, along with an outline of implications and conclusions are then presented.
LITERATURE REVIEW

The global exponential adoption of mobile devices has spurred the growth of mobile related products and services. Revenue derived from global wireless sales is estimated at $1.2 trillion (Hoover's, 2015). Growth in the field of m-government can be directly related to the global proliferation of mobile devices. M-government is the use of mobile applications and devices for the delivery of government products and services. Through the use of wireless networks governments are able to communicate with citizens about current events and other relevant issues (Trimi & Shen, 2008). As citizens use mobile devices for many aspects of their personal and professional lives, there is also an inherent expectation that they can communicate with governments in a similar manner. Today's landscape of mobile devices includes cellular phones, smart phones, personal digital assistants, ipods, ipads, tablets, and others. With these different devices many users are able to connect via a wireless access point and perform tasks such as web browsing, e-mail retrieval, social media interaction, text messaging, location dependent activities and other mobile app functions.

One key component of smart phones is the ability to send and receive short message service (SMS). SMS has gained prominence in the field of m-government as an effective tool to communicate information to citizens. SMS originated over 30 years ago and is restricted to one hundred and sixty characters (Milian, 2009). The use of SMS is expected to continue to grow with an expectation of more than 8.7 trillion messages generated globally by the year 2015 (Cellular News, 2011). Governments around the world have capitalized on this technology, and are using SMS and mobility to reach citizens for a variety of different services.

Examples of the use of SMS in the m-government domain include; the distribution of examination results to students in Oman (Naqvi & Al-Shihi, 2009); checking vehicle registration in Houston, Texas (Trimi & Shen, 2008) and intelligent emergency response systems (Amailef & Lu, 2013).Overall governments recognize that the use of mobile technologies provides more venues for citizens to interact with them (Carroll, 2006) and there can be a resulting internal operational cost reduction (Trimi & Shen, 2008). One specific internal cost reduction in the m-government domain can occur when m-government is used to reduce communication costs. It will be more cost effective to communicate information to citizen consumers via SMS than phone calls or face-face interaction.

Another more recent area where governments are reaching out to mobile users is via the creation of m-gov apps. Mobile apps are a much more recent technology than SMS. Their use is also pervasive for mobile device owners. The primary platforms for mobile apps are apple and android devices. The platform wars between apple and android persists, with 75% downloaded apps happening in the android market and 17% for apple, but apple is generating more revenue because developers can charge more for apple apps (Smith, 2014).

Both SMS and mobile apps provide an opportunity for governments to engage directly with citizens. However, the user of mobile devices in the government domain is not void of challenges. One primary challenge pertains directly to the mobile devices themselves, since they can be restrictive to some users due to their small sizes and smaller screens (Carroll, 2006). For some individuals the cost of ownership including data plans and minutes can be prohibitive as well (Eriksson, 2012). Even with some pricing limitations mobile devices have had a high rate of penetration around the world. In fact prepaid phones are the norm in developing regions of the world (GSMA, 2015). In developing and emerging economies prepaid phone cards give access
to individuals that would not necessarily be able to afford a more expensive post-paid alternative as seen in some developed markets.

THEORETICAL FRAMEWORK

The cell phone is the most heavily adopted technology in the world, and it is currently owned by approximately 91% of the adult population in the United States (Rainie, 2013). In particular, younger Americans are very heavy users of smart phones and are more likely to download and use mobile apps (Yang, 2012). Mobile applications provide a gateway for direct access to services and content provided by a variety of businesses. The mobile apps landscape also includes effective interfaces for interaction in variety of social networking environments such as Facebook, Twitter, Instagram, and Youtube. Social networking is a core activity for mobile app users. Mobility is driving the growth of a new digital ecosystem characterized by online commerce, digital content and social media (GSMA, 2015). To examine the use of mobility by governments consumer models are used to determine how, when, and why individuals may decide to use m-government apps.

METHODOLOGY

To examine the constructs presented in the model I will examine state level government mobile apps, designed for the individual users. The apps are freely available multiple sites including direct government sources. These apps will be examined along a variety of dimensions including purpose, number of users, features available, cost (if any), to name a few. This study will follow a content analysis methodology.

IMPLICATION AND CONCLUSION

As a work-in-progress the finding are not currently available. However, the topic is relevant to the field of m-government, since it is important to reflect on the current state of the field. If government apps prove to be under-utilized or marginally used further analysis would be needed. Apps are a useful and effective way for businesses to communicate with customers and clients. If government are not capitalizing on these opportunities they may fall behind private sector entities and be unable to fill that gap into the future.

REFERENCES


Evolving Trade Structure Dynamics and European Integration: the case of the United Kingdom

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December 2016

ABSTRACT

On June 23, 2016, United Kingdom (UK) voted to leave the European Union (EU), which sent shock waves across currency and stock markets. The effect of so called Brexit on international trade is not obvious due to first of its kind exit of a member state from the EU and uncertainty about the terms on which UK is separating from the EU. Although exit negotiations have not been concluded, we could speculate about the direction UK trade might take by looking at the past developments bilateral EU and UK trade, and evolvement of British trade structure.

This research investigates endogenous trade patterns of UK starting from year 1995 to 2015. Over three distinct periods, paper takes into consideration such events as China’s admission to World Trade Organization (WTO), expansion and integration of the EU and possible effects of end of British membership in the EU. Although Britain and the EU has been active trading partners given their close proximity, trade with the EU has dwindled slightly and increased with outside EU partners, such as China. China experienced rapid export competitiveness boost, which coincided with decrease of British export competitiveness. Paper reveals trade structure dynamics highlighting slip of export competitiveness. Previous studies show mixed results on trade specialization shifts in export structure for major economies.

While looking at the past trends, paper envisages trade patterns for immediate years following Brexit. This paper has such objectives as: (1) analyze foreign trade composition and dynamics over the time, (2) reveal comparative export structure of British exports, and (3) empirically apply Markov chain model in analysis of the trade structure.

The paper is based on previous studies on empirical models of trade dynamics, transport and pedestrian trajectory prediction and income convergence, which employed Markov chain model. This model can be very successfully used in decision making and pattern prediction. By using most detailed trade data available at the HS1992 six-digit commodity classification level, paper looks at the relative competitiveness of British exports by analyzing evolvement of number of products in Balassa index classifications. We observe product movements across Balassa index classifications and compare stationary distributions. This paper contributes to the existing literature by using more detailed product groups, extended timeframe and new classification mobility indexes.

Study revealed that during the period when China entered into WTO, export competitiveness reduced more significantly than during the later stages, when European integration was at its fastest. Product mobility of UK export trade structure decreased, but positive trend has returned in recent years.

During first period, it was observed that Markov chain matrix predicted higher product comparative advantage, which did not confirm empirically. In further two periods, when standard deviation decreased, Markov chains were closer to empirical classifications. During the last period, analysis shows overall increase in Balassa index, with smaller increase in actual trade classification.

Research also observed decrease in the classification mobility. Mobility was decreasing over the observed period and reached lowest rating in the last period. During the mid-period, mobility of product classes showed negative tendency towards lower class level. The trend reversed during the last period.

Revealed comparative advantage, export structure, United Kingdom, European Union, Markov chain
THE PERILS OF RELYING ON STATE ECONOMIC PERFORMANCE RANKINGS WITHOUT ADJUSTING FOR HETEROGENEITY

A.E. Rodriguez & Brian Marks

Abstract

State performance rankings are ubiquitous. But most rankings fail to recognize the heterogeneity inherent in the seemingly "objective" variables utilized to structure the ordering. A more parsimonious representation can be accomplished by adjusting the ordering variable by its most important attributes.

To demonstrate the procedure, we utilize a state ranking based on Cumulative GDP Growth. We identify the relative importance and sensitivity of several popular variables used in explaining the variation in cumulative gdp growth performance among the states. Once identified, important variables can enhance the effectiveness of legislators and administrators’ policy-making efforts. State performance rankings are recast after adjusting cumulative gdp growth for the important drivers identified.

The period examined is 2004-2014. To identify the importance and sensitivity of predictors we utilize random forests via the R packages relaimpo, Boruta, and random forests. Partial dependence depictions of the critical variables identified enable policy inferences.

Specifically, we find that the top marginal personal tax rate and the number of state employees exert and uncommonly high influence in explaining variation in state performance rankings based on cumulative gdp-growth.

The method proposed here is of general applicability and can be deployed to extract robust policy prescriptions based on a more accurate treatment of data given the limitations of traditional econometric models.

DRAFT: January 8, 2017

JEL: C43, M21, H70, R15

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Relative performance among states is routinely gauged across any number of indicators. These indicators could be individual, conventional indicators such as gross domestic product per capita or employment growth or they could be composite indicators assembled algorithmically from elementary variables. The ordering provided by performance measures simplify often complex debates by reducing the dimensions involved thereby facilitating comparisons and benchmarking. Rankings compel the questioning of individual standings. The ranks invite attention from the media and policymakers and, increasingly, from the general public – leading invariably to finger-pointing or high-fives. And thus, almost inevitably rankings constitute invitations to look more closely at the explanations that underlie them (Saltelli 2007).

Despite their seeming intuitive simplicity, the construction and usefulness of composite indicators has been severely criticized - if not compromised (Artz, et al. 2016, Kolko, Neumark and Cuellar-Mejia 2013, Paruolo, Saisana and Saltelli 2012, Gladwell 2011). Less scrutiny however, has been given to the capability of individual economic indicators used for purposes of state performance rankings. Unfortunately, individual indicators – such as State GDP Growth, Absolute Net Migration or Employment Growth, inter alia – may betray an unwanted heterogeneity that distorts the resulting ordering. For instance, an ordering based on State Gross Domestic Product would most likely rank more populous states higher and thereby convey a misleading sense of a state’s relative performance.

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2 There are many examples. For one instance of the comparative use of economic indicators see "New England Economic Indicators," Federal Reserve Bank of Boston [https://www.boston-fed.org/publications/new-england-economic-indicators.aspx]. For an example of a composite indicator-based ranking see the Freedom in the 50 States ranking published by the Cato Institute [https://www.freedominthe50states.org/].

Some of the disparity in a GDP-based ranking is isolated by normalizing: the setting forth of a common denominator. Thus, and perhaps obviously, GDP normalized by a state’s population into a new metric altogether is considered a more informative alternative than a standalone measure based on GDP.

However, the reason for reducing GDP by a state’s population – isolating the desired dimension to curtail the likelihood of biased performance metrics - applies with equal force to any number of variables. Put differently, should we not adjust GDP by other variables to fully extract a more representative economic performance signal? Because it is not clear which other variables should be considered the issue of subjectivity in variable selection and domain relevance re-enters the debate (Sitglitz, Sen and Fitoussi 2009).

Yet, it is possible to examine and identify the most important variables in explaining the difference in seemingly objective performance metrics. In this paper we rely on the important-feature selection capabilities of random forests to identify the most important predictors of performance metric variability. With key drivers identified, state relative performance metrics are recast. Importantly, identifying the most important variables and their sensitivity constitutes a roadmap for policymakers intent of addressing shortcomings.

The methodology, references and sources of data are provided in this paper. The associated code is available upon request. The paper is arranged as follows. The next section provides a graph of state rankings based on cumulative growth in gdp. Cumulative growth in gdp stands as our archetypical example. The third section contains a discussion of random forests and feature selection. The fourth section contains our results. The last section concludes.

**Relative Performance Among 50 States**

The period examined is 2004-2014 and encompasses the fifty states of the United States. Relative performance is gauged from three perspectives: Cumulative Growth in State Gross Domestic Product, Absolute Domestic Migration, and Cumulative Employment...
Growth. All three performance variables are responsive to state policymakers’ prescriptions. And all three variables are recurring in policy and political debates.

Figure 1 provides a visual depiction of the associated ordering induced by a specific performance variable. Specifically, Figure 1 displays states rank in terms of cumulative GDP growth across the period examined. To conserve space, Figure 2 & Figure 3 are displayed in the appendix to this paper. They display how states rank in terms of cumulative employment growth and absolute net migration.

We resort to a machine learning algorithm because is empirically difficult to isolate the key explanatory variables responsible for GDP growth using conventional econometric methods. In fact, researchers have tested numerous explanatory variables and resorted to a dizzying array of econometric approaches in attempting to explain factors
underscoring the realized difference in the relative performance of states based on GDP growth. A sampling of recent work in this area include differences in tax policy (McBride 2012, Gale, Krupkin and Rueben 2015, Segura III 2016), on the composition of clusters (Delgado, Porter and Stern 2012), on historical industry structure (Higgins, Levy, and Young, 2006), and knowledge and technology (Moretti 2012, Glaeser 2011, Florida 2002).

There are other technical glitches that diminish the power of individual metrics in ordered unadjusted rankings. Few studies can reach the entire population. The performance variable is assembled by surveying samples of a population; as such it admits sampling error. The magnitude of resulting margin of error may be sufficiently wide to vitiate any meaningful difference between any two consecutive positions in the resulting orderings. Thus, for example and arguyendo, despite a seeming difference in gdp growth between two states ranked 20th and 21st the observed difference cannot be established as being significantly different from zero – thus rendering the ordering meaningless. Generally, the closer the resulting values are to each other the higher is the probability of error in the ranking. To illustrate this statistical artifact, Figure 2 below displays the state ranking based on cumulative gdp growth. The graph includes estimated confidence intervals around each of the results obtained for each of the sampling units. At the very least, the overlapping confidence intervals suggest caution in the interpretation of the resulting ordering.

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4 The confidence intervals are those associated with the forecast dependent variable of a linear model fitting cumulative gdp growth to the fifteen original explanatory variables.
The procedure for adjusting for heterogeneity proposed here is unlikely to eliminate altogether the confidence interval associated with the predicted dependent variable. But it is likely to reduce the margin of error.

**Predictor Importance**

There are numerous qualitative and quantitative approaches to determine predictor importance. Analysis of variance, principal components analysis, factor analysis, discriminant analysis, multivariate regression, various machine learning algorithms, and logistic regression *inter alia* are commonly used to relate attributes to dependent variables (LeBreton, Ployhart and Ladd 2004). All these procedures are capable of ascribing predictor influence on the variability of the response variable.

Driver importance is a difficult task across the board but especially vexing in the performance indicator literature. The difficulty lies in the fact that many economic variables reflect overlapping concepts thereby jointly contributing to the variability of the de-
ependent variable. Moreover, various steps in the construction of an index can be subjective. The process tends to artfully reflect their author’s remit, or – as the case might be, their ideological leanings, theoretical preconceptions, their political identity or agenda. The variables selected, variable construction, the aggregation procedure, the time period encompassed, and the weights utilized provide considerable leeway to an index builder to shape or assist a narrative (Nardo, et al. 2005, Sitglitz, Sen and Fitoussi 2009). In addition, because of the interactions among attributes it is difficult to isolate the net effect or individual contribution of an attribute to the dependent variable.

**The Relative Importance of the Determinants of Performance**

We scrutinize fifteen variables as potentially relevant explanatory variables for the realized variance in state rankings. The data is obtained from Laffer, et al (Laffer, Moore and Williams 2016). Each of the variables are policy variables – presumably in control of State elected officials and administrators.

We use Random Forests to extract the importance of variables in explaining the performance metric. Operationally, a large number of unpruned trees is constructed. A random sample of predictors is taken before each node is split and classification turns on the majority vote of the full set of trees (Kuhn and Johnson 2013).

Random Forests is a machine learning technique ideally suited for the type of data assembled here. First the variables are mixed-types: binary and numeric. Second, the number of explanatory variable is large compared to the number of observations. Third, the variables are correlated and some highly correlated. Non-independence can affect standard error estimates used to determine statistical significance.

Random Forests is a non-parametric algorithm which requires no distributional assumptions and no explicit model; rather, it infers nonlinearities and interactions from the data. RF’s ability to approximate arbitrary functional forms and thus its ability to identify the presence of complex nonlinear relationships accounts for its enhanced performance over conventional models in econometrics. The latter require an explicit specification of the relationship between explanatory and outcome variables.
We use the R packages *random forest*, *party*, *boruta*, and *relaimpo* to extract predictor importance and sensitivities. The importance of variables is assessed by their impact on the accuracy of predictions. These packages deploy several procedures to assign to each predictor its percent contribution to the total variance explained. This allows for a ready assessment of a predictor for the outcome of interest. The results presented below are based on the averaging of the sequential sum-of-squares obtained from all the possible orderings of the predictors (Gromping, 2006). This procedure of identifying the relative contribution to a joint outcome is conceptually a Shapley Value consideration and an application of Shapley Value Regression (Lipovetsky & Conklin, 2001).\(^5\)

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\(^5\) Lloyd Shapley was concerned with the fair allocation of profits gained collectively by several actors. In effect, he studied how to fairly estimate the importance of each actor to an overall result where each actor varied in their contribution of effort. Shapley passed earlier this year.
The level of government employees accounts for a significant portion of the variation in cumulative GDP growth. The top marginal personal income tax rate contributes significantly as well. Table below presents the two variables deemed important-predictors.
Table 1

Cumulative GDP per Capita

<table>
<thead>
<tr>
<th>Public Employees per 10,000 of Population</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top Marginal Personal Income Tax Rate</td>
</tr>
</tbody>
</table>

Sensitivity Analysis

How are the identified “most important” variables related to performance? It is possible to obtain a visual display of the marginal effect on the performance variable of the variables identified as most important. Here, for instance, we see the relationship between the top marginal income rate and cumulative gdp growth rate.
Figure 5

Growth on the Top Marginal Personal Income Tax Rate

Figure 4

Partial Dependence Cumulative GDP Growth
Growth on Number Public Employees per 10,000 Residents
In order to aggregate the identified important drivers into a composite index of performance, we calculate the predicted values of a linear model relating cumulative GDP growth and the two identified drives. The resulting predicted values are used to calculate the relative state rankings. The results are presented below.

**Figure 6**

![Graph showing Cumulative GDP Growth Adjusted for Variable Importance over states]

**Concluding Comments**

We rely on random forest R packages to dissemble Cumulative GDP Growth in search of the most influential policy variables. Largely due to the significant multicollinearity of the predictive variables, and the small-sample multiple-variable character of the problem at hand random forests outperforms conventional multiple regression methodology.
At least two important drivers of state economic performance based on cumulative GDP growth are identified. The number of employees in government service and the top marginal income tax rate exert considerable influence on the realized outcomes. The revised rankings based on the predicted scores of the performance variable are likely to be more reliable than the one based on the unadjusted metric.

References


## Appendix

### Table 2: Variable Definitions

<table>
<thead>
<tr>
<th>Variable Definition</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top Marginal Personal Income Tax Rate</td>
<td>The marginal tax rate is the percentage taken from your next dollar of taxable income above a pre-defined income threshold. The marginal tax rate includes federal, state and local income taxes, as well as federal payroll and self-employment taxes.</td>
</tr>
<tr>
<td>Top Marginal Corporate Income Tax Rate</td>
<td>The amount of state tax – as a percent - paid by Corporations on the additional dollar of income earned; includes local taxes if any.</td>
</tr>
<tr>
<td>Personal Income Tax Progressivity</td>
<td>This measures the difference between the average tax liability per $1000 at incomes of $50,000 and $150,000. The average tax rate is the total tax paid as a percentage of total income earned.</td>
</tr>
<tr>
<td>Property Tax Burden</td>
<td>Tax revenues from property taxes per $1,000 of personal income.</td>
</tr>
<tr>
<td>Sales Tax Burden</td>
<td>Tax revenues from sales taxes per $1,000 of personal income.</td>
</tr>
<tr>
<td>Remaining Tax Burden</td>
<td>Tax revenues from all taxes per $1,000 of personal income. It excludes personal income, corporate income, property, sales and severance taxes.</td>
</tr>
<tr>
<td>Estate/Inheritance Tax Levied?</td>
<td>Yes or No.</td>
</tr>
<tr>
<td>Recently Legislated Tax Changes</td>
<td>Relative change in tax burden over the 2014-2015 legislative session.</td>
</tr>
<tr>
<td>Debt Service as a Share of Tax Revenue</td>
<td>Interest paid on debt as a percentage of total tax revenue.</td>
</tr>
<tr>
<td>Public Employees per 10,000 of Population</td>
<td>Full-time equivalent public employees per 1,000 population.</td>
</tr>
<tr>
<td>State Liability System Survey</td>
<td>Quality of state legal system. A ranking of tort systems by state.</td>
</tr>
<tr>
<td>State Minimum Wage</td>
<td>State minimum wage, if applicable. Otherwise the federal rate is used.</td>
</tr>
<tr>
<td>Average Workers’ Compensation Costs</td>
<td>Worker’s Compensation Index Rate per $100 of payroll.</td>
</tr>
<tr>
<td>Right to Work State?</td>
<td>Yes or No. Whether a state requires union memberships for its employees.</td>
</tr>
<tr>
<td>Number of Tax Expenditure Limits</td>
<td>Whether the state has a (i) a state expenditure limit; (ii) mandatory voter approval of tax increases; and (iii) a supermajority requirement for tax increases.</td>
</tr>
</tbody>
</table>

Source: (Laffer, Moore, & Williams, 2016).
<table>
<thead>
<tr>
<th>Cumulative GDP per Capita</th>
<th>Net Migration</th>
<th>Cumulative Employment Growth</th>
</tr>
</thead>
<tbody>
<tr>
<td>Public Employees per 10,000 of Population</td>
<td>Top Marginal Personal Income Tax Rate</td>
<td>State Liability System Survey</td>
</tr>
<tr>
<td>Top Marginal Personal Income Tax Rate</td>
<td>Average Workers’ Compensation Costs</td>
<td>Top Marginal Personal Income Tax Rate</td>
</tr>
</tbody>
</table>

**Figure 7**
Figure 10

Partial Dependence of Net Migration Growth on Workers' Compensation Costs
Figure 11

Partial Dependence of Employment Growth on the Top Marginal Personal Income Tax Rate
Partial Dependence of Employment Growth on the Quality of the State Legal System
THE VALIDITY OF CONSUMER SENTIMENT IN SMALL-AREA ECONOMIC FORECASTING: A NAÏVE BAYES ANALYSIS

A.E. Rodriguez & Carolyne Cebrian*

Abstract

Obtaining an accurate picture of the current state and direction of the regional economy is particularly important to local decision-makers, including shopkeepers, academic institutions, and state and local government agencies.

Traditional, survey-based sentiment indices have long-existed and are used for this purpose. But current abilities to source online data to map consumer sentiment has kindled interest in their usefulness in regional economic forecasting. The appeal of tailored sentiment indices and other similar online-sourced measures are their seeming immediacy and their ability to capture information in more relevant geographic and product domains – which is believed to enhance their capability of improving predictive metrics.

If decision-makers are to profitably rely with reasonable confidence from the increased availability of localized sentiment indices they will have to learn to effectively integrate domain knowledge, tailored online sentiment indices and traditional data. Perhaps more importantly, users will have to be assured of sentiment index validity in enhancing regional economic forecasts. We test sentiment index relevance in this paper reproducing results of a popular local forecast.

Specifically, we appraise whether there are measurable improvements from the presence of a publicly available sentiment index to the New Haven Register’s Economic Scorecard, a popular regional forecast model. The model is a binary directional prediction model. Succinctly, we find measurable improvements in the model’s predictive accuracy of the Economic Scorecard. We speculate as to the generalizability of our results, especially regarding the use of other online-sourced nowcasting metrics.

DRAFT: February 20, 2017

JEL: C43, M21, H70, R15

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As do many individuals, business operators and establishments often forge their economic understanding of local business conditions from a combination of sources: local media business analysts, newscasts, specialized web-sites, published government statistics, inter alia.

Obtaining an accurate picture of the current state of the economy is critical to all of us, but it is especially important to regional economic decision-makers. There are countless localized economic forecasting models in service of this effort throughout the country. Their coverage scope varies: they range from metropolitan area ones, statewide ones, to multi-state or regional forecasts.

For the most part, these models rely on conventional statistical models and conventional economic time series as reported by state and federal government agencies. Both conventions are beset with considerable problems.

There are any number of limitations associated with reliance on statistics gathered and provided by the federal government. For instance, much of the data assembled reflect historical, pre-establish zones and areas, jurisdictions which may not necessarily reflect current circumstances, nor the circumstances of all. Another limitation, an especially critical one is the reporting lag – federal supplied data are provided often several months in arrears.

Thus, to improve forecast accuracy, forecast specialists and analysts often incorporate regional or contemporaneous information into their models: consumer sentiment indexes are a popular choice. And historically, the sentiment indexes of choice were ones assembled via traditional survey methods.

But do sentiment indexes contribute to forecast accuracy or improving forecasts generally? This is an especially important question nowadays, because of the current ability for forecasters to draw online-data sourced indices.

It is possible to construct and use tailored sentiment indices given the increased availability of social and online data, what is known generally as “nowcasting” (Choi & Varian, 2009) (Das & Chen, 2007) (Scott & Varian, 2013) (Mago, 2016).¹ These nowcasting indices can be crafted to cover a particular zone or region in a manner that conventionally sourced statistics cannot.

If both professional forecasters and practical decision-makers who are capable of constructing their own forecasts are to profitably rely with reasonable confidence from the increased availability of sentiment indices, they will have to learn to effectively integrate domain knowledge, conventional or tailored online sentiment indices and traditional data. Perhaps more importantly, users will have to be assured of sentiment index validity in enhancing regional, area economic forecasts.

Studies that have previously examined the question of sentiment index-enhanced economic forecasts have found a connection between sentiment and relevant economic variables, such

¹ There has been an increased interest in the relevance of consumer sentiment and consumer confidence as a result of a renewed interest into Keynesian “animal spirits” explanations for the great recession. See, e.g. (de Bondt & Schiatti, 2015).

However, most of these previous studies were conventional statistical econometric models. And most appraisals of sentiment validity relied on traditional consumer sentiment indicators such those constructed by the University of Michigan and the Conference Board’s Survey Indices.

We test sentiment index relevance in this paper reproducing results of a popular New Haven, Connecticut regional model. Specifically, we appraise whether there are measurable improvements from the presence of a sentiment index in the input-variable set of the New Haven Register’s Economic Scorecard, a popular regional forecast model. The model is a binary directional prediction model and we use a Bayesian net classifier algorithm.

Thus our inquiry as to the validity of the sentiment index combines several literatures. Succinctly, we rely on machine learning algorithms to estimate bidirectional predictive models for purposes of determining the predictive relevance of sentiment indexes.

All aspects of our work is set forth in this paper. It is structured as follows. The next section provides a description of the forecast-making process. It highlights the embedded sources of possible forecast error. The third section discusses the relevance of the chosen model – noting that it is especially well suited to handle the observed data and data-construction limitations. Bayesian models are known to closely resembling decision-making in financial and economic markets. Section four discusses the model, the data and the results. The last section concludes with a discussion of the generalizability of the results.
FORECASTING

Forecasts derived from economic models are often simply reported. At other times, the reporting conduit is via a commentator or analysis, although an explicit or implicit economic model underscores the analysis and commentary provided. A typical sequence of events leading up to a professional analyst forecast goes something like this: the analyst/forecaster waits for applicable data to be served up by the Bureau of Labor Statistics or relevant government agency at pre-announced release dates; the analyst then acknowledges the information provided in the release with some pithy comment; she then combines the insights from the data judiciously with professional experience; and then projects accordingly. Of course, the analyst’s seeming success corresponds almost precisely with her ability to avoid both categorical statements and declarative sentences and on her skill in couching the prediction in the finest two-handed language possible.

Here is an example of this routine. It is drawn from a relatively recent report in our local, regional newspaper but it is not unlike those likely to be found in any, and practically every, regional newspaper, radio, TV station, and online media outlet across the country. It is a ritual keenly tuned to the release dates of official economic data.

The area economy will have recovered all of the jobs it lost during the last recession. Through November, New Haven and surrounding communities had recovered 94.3 percent of the jobs that were lost...

For the second month in a row, the scorecard for November showed six of the eight indicators headed in a positive direction.

“New Haven is clearly out-performing the state as a whole,” ... “This is a continuation of what started happening earlier this fall and it should continue well into 2015.”

And notwithstanding the carefully crafted ambiguity and deliberate imprecision the forecast provided by our local media expert is, in turn, folded into our individual analysis by the rest of us, individuals, shop-keepers, managers, government employees, academic administrators, to organize and plan our next steps accordingly.

The problems with this exercise are numerous but invariably include the following two. The first is that the analyst cited in the article is relying on dated data. November figures are used to inform a late January forecast! This is a well-known shortcoming of our official statistical reporting system. And it is a handicap especially unhelpful for businesses organizations burdened with long-lead times in production and distribution such as the fashion (retail) industry and the toy industry.

A second problem follows from the fact that the data reflects a pre-selected frame or category of analysis that may resemble a user’s situation only partially or indirectly. For example, Figure 1 provides a visual representation of the reported unemployment rates that contain applicable information for our local economy. Waterbury and Danbury are small cities approximately 34 miles apart. As can be seen, the variation among the reported rates is enormous. Within Connecticut alone, the difference in the unemployment rates between

---

2 (Turmelle, 2015) The underlining of the last phrase is our doing.
Danbury and Waterbury averaged 2.7 standard deviations and reached a maximum difference of 3.5 standard deviations in November of 2010.\(^3\)

![Figure 1](image)

Clearly, the unemployment figure for the region or sub-region used by the analysts, necessarily an aggregate, may disguise important variation in the underlying data. Thus, the particular rate relied upon by the original analysts to form his or her opinion is critically important. In fact, as can be seen in the example cited above, the particular instance of the unemployment rate (or applicable statistic) is often left unreported.

By appealing to an unemployment rate calculated over a particular town or area solves what is known generally as the “reference-class” problem or as the “partition” problem (Colyvan & Regan, 2007). The problem arises because there is no a priori way to privilege one classification over another and therefore any proposed outcome is infinitely malleable. For economic series in general this might appear to be nitpicking because many current series reflect reasonable commonly established and accepted boundaries that define the partition set at hand. In fact, to a large extent these boundaries have been defined by common practice. The problem arises when the users fall outside the original intended audience. Thus, returning to the graph above, if you are a resident of Southbury, a town halfway between Danbury and Waterbury – which unemployment rate applies to you?

There is a derivative problem. There are simply too much data. Indeed, FRED, the Federal Reserve Economic Database alone boasts of 247,000 time series from 77 sources.\(^4\) In

\(^3\) These statistics are calculated using Bureau of Labor Statistic for Seasonally Adjusted Unemployment Rates for Connecticut, Waterbury and Danbury for the following period August 2007-February 2015; the Waterbury and Danbury series are New England Cities and Town Areas (NECTA). The US and New England series are also BLS monthly, seasonally adjusted series. The standard deviation is the difference between the reported rates for Waterbury and Danbury divided by the standard deviation of the reported SA-Unemployment series for Connecticut.

\(^4\) This is how a recent announcement issued by the National Science Foundation characterizes the explosion of data, “Data may originate from many disparate sources,
perhaps a variant of Fredkin’s paradox we are paralyzed, incapable of deciding when confronted with choices among and between similar series. The massive amounts of data are effectively useless when combined with our inability to successfully separate the signal from the overwhelming noise. And perhaps this is what drives us to rely on more idiosyncratic, contemporaneous data. We turn to examine whether this heuristic is a valid one.

RELEVANT LITERATURE

Once a regional forecast is advanced there is evidence to suggest that it is routinely interpreted, by laymen and individuals, in a simple binary manner: whether “things” will get better, or not. This, simplification suggests a wariness of the false precision imparted in level forecasts. In fact, as a general principle it is probably wise to view most economic and financial forecasts with some modicum of caution, especially given economic and financial forecasting’s poor track record recently.

The New Haven Register, the influential, regional newspaper in the broader New Haven, Connecticut area, publishes a popular forecast which they call the “Economic Scorecard.” It is an instance of a binary directional prediction model which relies on a conventional set of Economic time series. The model returns an outcome that is described as either “thumbs-up,” or “thumbs-down.”

There are considerable parallels between the data generation model underscoring local area and regional models and those underscoring price movements. Thus, we can apply the binary price directional prediction models used for forecasting movements in market indices, individual prices, inter alia, to the Economic Scorecard model and determine whether the presence of a sentiment index improves its forecast accuracy.

Machine Learning Applications of Binary Directional Prediction Models

The literature from which to draw from is considerable. Over the last decade or so, market directionality appraisals featuring machine learning algorithms have gained popularity in both academic and professional research and practice. The binary time series problem in these studies is typically modeled as a two-class supervised learning classification problem where the analyst is interested in the direction of stock market indices, individual shares, exchange rates, inter alia. The algorithmic task is to predict classes by examining historical instances of classification given a set of attributes.

including scientific instruments, medical devices, telescopes, microscopes, satellites; digitally-authored media, including text, images, audio, and emails; streaming data from weblogs, videos, financial/commercial transactions; from ubiquitous sensing and control applications in engineered and natural systems, through multitudes of heterogeneous sensors and controllers instrumenting these systems; social interactional data from social networking sites, twitter feeds and click streams; administrative data; or scientific data from large-scale surveys, brain research, large-scale simulations, continuous simulation models, and computational analyses of observational data. The data can be temporal, spatial, or dynamic; structured or unstructured; and the information and knowledge derived from data can differ in representation, complexity, granularity, context, quality, provenance, reliability, trustworthiness, and scope.”

In studies examining direction of change, changes are classified as 0 or 1. Changes in the level prices are typically, although not exclusively, examined on a day-to-day basis. Accordingly, a class value of 0 means that the present day’s price is less than the previous day; a fall in the price of the stock. Similarly, a class value of 1 means that the present day’s price is greater than the previous day; a rise in the stock price.

The specific literature on machine learning-based bidirectional prediction alone is extensive.

Kumar and Thenmozhi examine the predictability of the direction of stock index movement by means of machine learning methods (Kumar & Thenmozhi, 2006). They deploy classification models, such as Linear Discriminant Analysis, logit, artificial neural network, Random Forests, and Support Vector Machines.

Choudhry and Garg deploy a support vector machine; they select the set of attributes with a genetic algorithm (Choudhry & Garg, 2008). Juan et al, also resort to support vector machine algorithms and other machine learning methods for predicting stock market direction. Researchers and commentators have relied on other modeling algorithms to examine binary direction models; these include autoregressive models, the Generalized Linear Model or a Hidden Markov Model. Startz, for instance, applies binary autoregressive models and markov processes to US recession data (Startz, 2012). Bicego and co-authors, resort to Hidden Markov Modeling to identify and predict the sign in short financial trends (Bicego, Grosso, & Otranto, 2008).

As a general point, classification models such as linear discriminant analysis and logit used for the direction of stock index movement outperform the level estimation methods such as exponential smoothing or multilayered feed-forward neural networks (Leung, Daouk, & Chen, 2000).

**Sentiment Indexes as Predictors**

According to Loewenstein, the emotions and feelings experienced at the time of making a decision “often propel behavior in directions that are different from that dictated by a weighing of the long-term costs and benefits of disparate actions (Loewenstein, 2000).” In fact, the model developed by Loewenstein et al., purposefully accounts for the fact that the emotions or sentiments that individuals experience at the time of making a decision influence their eventual decisions. Consumer purchases, for example, may involve an awareness or sensitivity of the tradeoffs between a local or regional economic horizon and present needs. It seems reasonable to hypothesize that the emotions and feelings derived from regionally idiosyncratic events influence consumer’s purchasing decisions. Thus, small area model-based predictions are likely to gain in efficiency to the extent that sentiment indexes reflect current or transient factors or events in the particular geography.

Choi & Varian showed how the fluctuations in the frequency with which people online search for certain words or phrases improve the accuracy of econometric models used to predict economic indicators (Choi & Varian, 2009). Choi and Varian’s work launched a vigorous research program into “nowcasting” where quantifiable snapshots of current events are extracted via statistical learning methods from social networks such as Facebook, Twitter on web-scraping and text-mining (Ginsberg, et al., 2009). This vast amount of data capture useful information driven by everyday life.
The New Haven Economic Scorecard

The New Haven Register’s Economic Scorecard is an implicit multi-attribute scoring model. It is a linear unweighted sum of seven conventional economic time series. The Economic Scorecard popularity is derived from its simplicity. The model relies on a simple appraisal of the change in the various economic series. A series, total employment for example, is a “thumbs-up” if it has increased from the same month in the previous year; obviously, a “thumbs-down” if it has experienced a decrease over the period. The model’s eight constituent series are transformed in this manner into a binary score. The individual series’ binary score is then summed; thus, the score is at its maximum of 8 if all the attributes result in a “1.”

\[
\text{Index Score} = IS = \sum v_i
\]

where, \(i = 1,8\), and

and, for all \(i\):

\[
v_i = \begin{cases} 
0 & \text{iff } \Delta v_i < 0 \\
1 & \text{iff } \Delta v_i > 0
\end{cases}
\]

The last step is taken by the analyst and it entails an ad hoc determination of the cutoff threshold. Based on the associated analysis by the Scorecard authors of the March Economic Scorecard we establish that any score greater than or equal to a score of five is considered an aggregate thumbs-up.

\[
IS = \begin{cases} 
1 & \text{if } \sum v_i >= 5 \\
0 & \text{if } \sum v_i < 5
\end{cases}
\]

This result is then announced as the predicted monthly outlook for the region.

Application of a Naïve Bayes Model to Estimate Directionality

To model the binary directional predictive process and appraise the relevance of sentiment indices in a realistic setting we use the simplest form of a Bayes network, the Naive Bayes classifier. Naïve Bayes has been used across a wide variety of fields including RNA sequencing, disease diagnosis, image classification and spam filtering (Raschka, 2014).

The Naive Bayes algorithm is a simple classifier that calculates a set of probabilities. It counts the frequency and combinations of values in a given set of attributes. The algorithm

\(^5\) The sole exception if for the unemployment series. It is ascribed a “thumbs-up” if it declines for the month relative to the same month the previous year, and viceversa.
uses Bayes theorem and assumes all attributes to be independent given the value of the class variable.

The most likely class given an attribute, $v$, and a class, $C$, is:

$$\text{Class} = \arg\max P(C/v)$$

and

$$\text{Class} = \arg\max \frac{P(v/C)P(C)}{P(v)}$$

The conditional independence assumption rarely holds true in real world applications and leads to the appellate “naïve” assigned to the algorithm. Yet Naive Bayes tends to perform well and learn rapidly in various supervised classification problems (Domingos & Pezzani, 1997) (Zhang, 2004). The performance of the algorithm is determined by the accuracy of the classification. Classification accuracy is calculated by determining the percentage of tuples placed in a correct class.

To appraise the relevance of the sentiment index, the model is first estimated with the actual sentiment index. This outcome is then compared to the outcome of the same model with the sentiment index replaced by a randomly generated one within the model.

All data is obtained from publicly available sources listed in the Appendix to this paper. The data is monthly data encompassing the period January 2007 through and including December 2016. Incidentally, December 2016 is the last date available for all the data series utilized by the Economic Scorecard reconstruction in this paper – revised on February 20, 2017.

Results

The confusion matrix is generated for class Outlook having two possible values i.e. positive (1) and negative (0). The result for the model containing the published sentiment index:

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<th>Negative</th>
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<tbody>
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<td>12</td>
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<tr>
<td>Negative</td>
<td>6</td>
<td>50</td>
</tr>
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</table>

The confusion matrix with the randomized Sentiment Index:
We report accuracy and kappa to appraise classifier performance. The Kappa statistic compares an observed accuracy with an expected accuracy. The deterioration in both the reported accuracy the kappa statistic is noticeable – as seen from the diagnostic statistics in the tables above and displayed in the figures below.
Is the observed difference between the two outcomes statistically significant? A Bonferroni adjusted statistical test of significance does find a meaningful statistically significant difference – at a 5 percent level - in the performance statistics. They are reported here:

p-value adjustment: bonferroni
Upper diagonal: estimates of the difference
Lower diagonal: p-value for H0: difference = 0

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<td>NB_Random</td>
<td>0.04302</td>
<td>0.04177</td>
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</table>
The results suggest that the sentiment index conveys useful information for purposes of enhancing predictive accuracy.

**Concluding Comments**

Our results suggest that the presence of the sentiment index in the Economic Scorecard model measurably improves forecast accuracy. Importantly, our result does convey some weight to decision-makers’ reliance on idiosyncratic indicators and on constructed sentiment indexes – such as those assembled from online-sources.

The use of sentiment and opinion information is already incorporated into local-area decision-making. Analysts routinely drawing insights into a region’s outlook by identifying and tracking non-traditional indicators and data sources capable of providing a more idiosyncratic understanding of a region’s performance. Regional and city planners are now using localized urban information such as subway passenger traffic, Broadway ticket sales, parking garage usage counts, and the average price of local apartments on Craig’s list to assist in the discerning of the future of their localities.6

Organizations, businesses and individuals routinely use tracking services such as customized RSS feeds, IceRocket, and Google’s Me on the Web among others to access “social-intelligence”, online social-media consumer sentiment and opinion.7 And with the ascendance and influence of Yelp, Facebook, Twitter, Rotten Tomatoes, and related online fora – where customers provide feedback and opinion, managers monitor their establishment’s reputation and performance by tracking web commentary. The popularity and widespread use of sentiment data suggests that users feel intuitively that opinion and sentiment indices convey a sense of the direction of consumer expectations and associated spending (Ludvingson, 2004) (Garrett, Hernandez-Murillo, & Owyang, 2005) (Mago, 2016).

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7 IceRocket is a free service – among many available providing social media and online tracking capabilities. Meltwater, the enterprise which provides IceRocket services, for a fee, offers more tracking sophisticated capabilities. There are many other similar enterprises available. By referencing them in this paper, we are neither endorsing nor recommending Meltwater; we are merely alluding to them as a representative provider. [http://www.meltwater.com/products/?utm_source=IceRocket&utm_medium=banner&utm_campaign=mBuzz_Social_Software](http://www.meltwater.com/products/?utm_source=IceRocket&utm_medium=banner&utm_campaign=mBuzz_Social_Software) For another example, see, also, e.g., socialmention; [http://socialmention.com/](http://socialmention.com/).
Heuristically, local data – replete with intuitive and familiar features - may prove to be more comforting and natural to use in gauging a future local event. Localized, relatable data may facilitate the formation of more relevant interpretive mental models, narratives or algorithms required to process the assembled data – primarily because we have considerable more touchpoints necessary to inform experience.

With the framework that we advance here the information advantage of any particular constructed index can be appraised. It would unlikely convey end-user confidence to be assured that their favored idiosyncratic index is valid.

References


DATA APPENDIX

Data Treatment

To reproduce the Scorecard results we used the All Transactions House Price Index instead of the reported Warren Group home prices. We used monthly estimates of Weekly Earnings instead of Real Disposable Income. And we used the Michigan Sentiment Index instead of the Conference Board Consumer Confidence Index. All data was obtained from the Federal Reserve Economic Database via Quandl feeds. Housing Starts were for all of Connecticut instead of from the Connecticut Department of Economic & Community Development (DECD). According to the Scorecard authors they obtain their data from 12 area towns from CT DECD. The DECD data is very sparse and the aggregation of towns is probably meant to overcome a possible small numbers problem.

Data is monthly data encompassing 2007-January through, and including, 2016-December.

Summary Statistics

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<th>housing transactions</th>
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<th>total labor force</th>
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<td>Mean 321031.1</td>
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<tr>
<td>Median</td>
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<td>Median 322066.0</td>
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<th>housing starts</th>
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### Conditional probabilities

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EXPLORING ENTREPRENEURSHIP AND ITS DRIVERS AT A COUNTRY LEVEL USING ANALYTICS

Viju Raghupathi, Koppelman School of Business, Brooklyn College of City University of New York, Vraghupathi@brooklyn.cuny.edu

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ABSTRACT

The current research explores the phenomenon of entrepreneurship and its drivers in the economy at a country level. We look at the environment of entrepreneurship in terms of the entities of government, finance, and education. The data for 2001-2015 are collected from the General Entrepreneurship Monitor (GEM) database for a total of 22 countries in high and upper middle income levels. The indicators for entrepreneurship include entrepreneurial intention, nascent entrepreneurship rate, established ownership rate, new business ownership rate, perceived capabilities, perceived opportunities, and total early stage entrepreneurial activity for male and female working age population. Government indicators include governmental support and policies, taxes and bureaucracy, governmental programs, R&D transfer, commercial and professional infrastructure. Education indicators basic school entrepreneurial education and training, and post school entrepreneurial education and training. Finance indicators include financing for entrepreneurs, and cost of starting a business. The data are analyzed using the analytic tool Tableau.

Our results show that governmental taxes and policies along with R&D efforts encourage entrepreneurship for high and upper middle income countries. Surprisingly, infrastructure and financing show a positive association with entrepreneurship only for upper middle income, not for high income countries. In terms of education, post school education increases entrepreneurship more in upper middle income than in high income countries; basic school education increases entrepreneurship in upper middle income countries, but surprisingly has a negative impact for high income countries. In analyzing the role of entrepreneurial activity by gender, female entrepreneurial activity was higher in upper middle income countries, while male entrepreneurial activity was higher in high income countries.

Our findings offer suggestions for improving the entrepreneurship environment by focusing on key drivers. It brings into focus the integrated role of government and education in promoting an innovative environment. We highlight the differences globally between different income level countries, highlighting the varied perspectives that may have to be taken in taking entrepreneurship policy decisions.

Entrepreneurship, analytics, education, government, finance, drivers of entrepreneurship
Title: Innovation in Small Disadvantaged High-Tech Businesses: A Critical Review

Abstract

Small disadvantaged businesses do not appear to innovate as much or as quickly as small businesses. This is despite the availability of several government initiatives aimed at helping small disadvantaged businesses in particular. This research will present a critical review of innovation in small disadvantaged businesses, specifically those in the high-tech field. A representative sample of small, disadvantaged, high-tech businesses, primarily in the northeast region, will be surveyed via questionnaires in order to identify common characteristics and to describe the nature of innovation among such firms. Additionally, a technology management framework will be developed for modeling innovation in high-tech enterprises. The aim of this research is to develop a model used to quantify innovation, and to provide innovative technology management strategies to increase the level of innovation among small disadvantaged businesses. The proposed model will be validated using real-life case studies from the public domain. This research is needed to better understand why small disadvantaged high-tech businesses are less successful than their non-small counterparts. This research will support a doctoral dissertation and contribute to the body of knowledge in technology management.

Keywords: Small Disadvantaged Businesses, Technology Management, Innovation.
Can Individual Investors Use Technical Trading Rules to Beat the World Markets?

Thomas S. Coe, Quinnipiac University
Kittipong Laosethakul, Sacred Heart University
Catherine Anitha Manohar, Quinnipiac University

In traditional tests of the weak-form of the Efficient Markets Hypothesis, price return differences are found to be insufficient to develop trading rules to take advantages of historical price patterns. Yet, traders continue to use technical analysis to establish buy and sell decisions for various assets across markets. This study sets out to determine if there are consistently profitable techniques that can be applied for use in equities markets and compare the techniques for market-beating returns to traders who use them. Technical analysis, in contrast to fundamental analysis of assets, looks at the current price and relates this to past price history to determine the timing of buying and selling of stocks.

The sample of data presented here includes daily high, low and closing prices from the individual equities that comprised 17 various market indices in Asian and Pacific Rim countries. The data allows for a broad range of stocks over a relatively long period of time so that prices will not be entirely subject to specific events or market conditions. The sample period runs from December 31, 1995 through December 31, 2010. The data is currently being updated to address equities across Asian, European, Latin American and African markets through December 2016.

The trading techniques we employ are the arithmetic Moving Average (MA), the Relative Strength Index (RSI) and a Stochastic Oscillator (K). These are among the more popular, general techniques used by technical traders and the basis for many trading programs. The performance from using these trading tools will be contrasted against a naive buy-and-hold strategy over the same period.
Do Good Companies Have Female Directors or do Female Directors Make Good Companies?

The issue of Exogeneity

William Bosworth
Professor of Finance
Western New England University

Bryan Schmutz
Assistant Professor of Finance
Western New England University

Preliminary – Not For Quotation

Abstract

There has been growing interest the number of female members of the board of directors of publicly traded corporations. This interest arises from both concern about equality of opportunity and the belief that corporations are better governed when the board of directors comprises diverse views and experiences. Studies of whether firms benefit directly from diverse boards have produced mixed results but there has been an inexorable trend throughout both the developed and developing world to include more women among corporate directors. Associated with this trend is increasing evidence that well-performing firms tend to have gender-diverse boards. But the issue of exogeneity has garnished little attention. Is it possible that firms that perform well offer directorships to women? Or does the presence of women lead to superior performance? This study finds evidence that well-governed firms do include women on the board and they benefit from better performance for doing so.

Introduction and Survey of the Literature

Social justice is the main impetus for including women and minorities at the highest level of corporate decision making. Several countries, including India, Norway, Germany, Italy and France have mandatory minimums for female participation. In the U.K. a group of large corporations have organized the “30% Club” that sets a target among their members to have at least a 30% female board representation by 2020. Barclays Bank issued an ETN (Exchange-Traded Note) last year called the Women in Leadership (WIL) ETN, composed of companies that have a female CEO or a minimum of 25% female directors on the board.

In the United States, a bill that was introduced to the U.S. Congress, The Gender Diversity in Corporate Leadership Act of 2016 (H.R.4718) would call on the SEC to establish a “Gender Diversity Advisory Group” to encourage female representation but would not mandate it. During the year 2015, men held 80.1% of S&P large cap 500 corporation board seats while women only held 19.9%. But of new directorships, 73.1% were awarded to men and 26.9% were awarded to women. (Catalyst, June 14, 2016). This suggests an asymptotic approach to 26.9% which is not far from 30%. But smaller firms are lagging far behind. For the S&P midcap 500 16% of the directors were women and for the S&P small cap 13% were women according to ISS data released in May 2016.
Earlier studies have concluded that female board representation is unrelated to firm performance (Carter, et. al., 2010; Rose, 2007; Shrader, Blackburn, & Iles, 1997). Some research has indicated that female membership has an adverse relationship to firm performance (Larcker, Richardson, & Tuna, 2007; Adams & Ferreira, 2009; Bøhren & Strøm, 2010; Darmadi, 2011; Minguez-Vera & Martin, 2011). More recent studies, however, find evidence that females improve the governance of the corporations (Nguyen & Faff, 2012, Schmid and Urban, 2015; Bosworth, Lee & Gu 2016).

The fact that some countries mandate female membership and others do not gives rise to an opportunity to study the effect of diverse boards on firm performance. Post & Byron (2015) concluded that there is no benefit from female participation on boards when it is imposed externally but there is when the board selects female directors voluntarily. Ahern & Dittmar (2012) find evidence consistent with Post & Byron. One of the issues of measuring the female board membership contribution to firm performance is the problem of endogeneity. It is possible that well-governed firms (or poorly governed firms) either welcome or avoid female participation and this may bias of the results any test of the female contribution to firm performance. Any accurate test of potential female contribution must answer the first question, what kinds of firms welcome female participation on the board of director? Why do firms add females to the board of directors if it is not to improve firm performance?

This question has been addressed by a small number of studies. Ferrall & Hersch (2001) found that firms that have at least one female on the board do so as a result of a self-imposed quota. Green & Homroy (2016) found that boards of companies where the CEOs who have fathered daughters are more likely to invite females to sit on the board.

The most obvious variable to test would be the firm performance itself. Do well performing firms hire more females or vice versa? Adams & Ferreira (2009) find evidence that females contribute to firm performance only when the firm is otherwise well-governed. But the present period of rapid transition provides a unique opportunity to thoroughly investigate the temporal causality between firm performance and female board membership.

A second possible driver for female board membership are institutional holdings of the firm’s stock. It is possible that large holders could put pressure on the Board to recruit female members. For example, the TiAa-CREF’s Policy on Statement on Corporate Governance states that the board should be composed of qualified individuals and should reflect diversity of experience, gender, race, and age. [TiAa-CREF] The California Public Employees’ Retirement System (CalPERS), the nation’s largest public pension fund, recommends that the board consider the mix of director characteristics, experiences, diverse perspectives and skill when nominating individuals to the board [CalPERS]. In the spring of 2017 State Street Global Advisors, the world’s third-largest asset manager, placed a bronze sculpture of a girl confronting the famous charging bull of Wall Street as part of an effort to call on the 3,500 companies it invests in to increase the number of women directors ahead of International Women’s Day. Gosh et. al. (2016) addressed the possibility of institutional influence indirectly. By subdividing their observation period of 16 years into an initial four-year base period and a series of subsequent two-year period they estimate the fluctuation in the market to book ratio due the fluctuating value that investors attach to female directorships. They find that female directorships increase following an increase in how investors value them. They could not, however, find a direct link between institutional holdings and female board memberships.
A third candidate is the set of board characteristics themselves. Are insular boards less likely to hire females? Do otherwise good governance characteristics lead to more diverse boards? Gosh et. al, (2016) find that the number of independent board members is positively associated with female directorships.

**Data and Research Design.**

Our hypotheses is that female directorships contribute to firm performance but firm performance does not contribute to the appointment to females on the board. First we check to see if our data is consistent with a positive association between female directorships and firm performance. Our test is in the form,

\[
Performance_{15} = \sum_{i=1}^{6} \alpha_i \times G15_i + Assets_{15} + \epsilon
\]

Where G15, is a governance characteristic. The independent variables are as follows:

- **F15**: The number of females that are directors (2015).
- **BSize15**: The number of directors sitting on the board (2015).
- **Bind15**: The percentage of directors that are independent (2015).
- **Duality15**: Whether the CEO is also Chair (2015).
- **Minority15**: The number of racial minorities on the board (2015).
- **Classified15**: Whether the board is staggered (2015).
- **Assets15**: The total assets of the firm (2015).

Our performance measures are Tobin’s Q (Q15) to measure financial performance and Return on Assets (ROA15) to measure operating performance. All data are for the year 2015.

Having done that, we check to see if there is reverse causality from firm performance to the decision to include women. Our test is in the form,

\[
F15 = \sum_{i=1}^{6} \alpha_i \times G12_i + Assets_{12} + \epsilon
\]

The list of dependent variables is the largely the same as in Equation 1 except they are all for the Year 2012, F15 is now the dependent variable and the performance measures are now independent variables,

- **BSize12**: The number of directors sitting on the board (2012).
- **Bind12**: The percentage of directors that are independent (2012).
- **Duality12**: Whether the CEO is also Chair (2012).
- **Minority12**: The number of racial minorities on the board (2012).
- **Classified12**: Whether the board is staggered (2012).
- **Assets12**: The total assets of the firm (2012).
- **Q12**: Tobin’s Q for 2012 (2012).
- **ROA12**: Return on Assets for (2012).
Our source of data is ISS (formerly IRRC) data from 2012 and 2015 on the S&P 1500 index companies and Compustat data for both of these years. We chose just two years in lieu of a time series because we believe board positions from year to year are not independent events and time series data may distort the estimated confidence interval. Mergers, Acquisitions and changes in revenues cause companies to move in and out of the S&P Index. This limits the number of usable observations to less than 1,500.

While not tabulated here, we also used Bloomberg data on institutional holdings decomposed into 20 kinds of institutions. However we found no evidence that institutional holdings play a role in the decision to invite females to sit on the board.

### Descriptive Statistics For Year 2012

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
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<td>0.79</td>
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<tr>
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<tr>
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<tr>
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<td>10</td>
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<tr>
<td>ClasBD12</td>
<td>1452</td>
<td>0</td>
<td>1</td>
<td>0.48</td>
<td>0.5</td>
</tr>
<tr>
<td>Q12</td>
<td>1551</td>
<td>0.53</td>
<td>106.6</td>
<td>1.81</td>
<td>2.89</td>
</tr>
<tr>
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<td>88.01</td>
<td>4.94</td>
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</tr>
<tr>
<td>AT12</td>
<td>1584</td>
<td>0.6</td>
<td>23B</td>
<td>20B9</td>
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</tr>
<tr>
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<td>1452</td>
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<tr>
<td>Valid N</td>
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</tr>
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</table>

**Descriptive Statistics for Year 2015**

<table>
<thead>
<tr>
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<th>Mean</th>
<th>Std. Deviation</th>
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</thead>
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<tr>
<td>Blnd15</td>
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<td>0.11</td>
</tr>
<tr>
<td>BSize15</td>
<td>1458</td>
<td>4</td>
<td>31</td>
<td>9.49</td>
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</tr>
<tr>
<td>Wom15</td>
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<td>8</td>
<td>1.56</td>
<td>1.14</td>
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<tr>
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<td>0.96</td>
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<tr>
<td>Q15</td>
<td>1495</td>
<td>0.51</td>
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<td>1.3</td>
</tr>
<tr>
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<td>10.51</td>
</tr>
<tr>
<td>AT15</td>
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<td>23.5B</td>
<td>23.68</td>
<td>11.98</td>
</tr>
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<td>0.54</td>
<td>0.5</td>
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<tr>
<td>Valid N(listwise)</td>
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<td></td>
<td></td>
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<td></td>
</tr>
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</table>
In order to reduce the influence of outliers Q and ROA were winsorized to ± 3 standard deviations about their mean. All variables in the regressions were transformed into z-scores.

Results

The results of our test are tabulated below. Columns (1) and (2) show that both financial and operating performance are influenced by governance characteristics.

<table>
<thead>
<tr>
<th>Year 2015</th>
<th>Year 2102</th>
</tr>
</thead>
<tbody>
<tr>
<td>(1)</td>
<td>(2)</td>
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<tr>
<td>D. Var Q15</td>
<td>ROAA15</td>
</tr>
<tr>
<td>F15</td>
<td>0.087***</td>
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<tr>
<td></td>
<td>(2.589)</td>
</tr>
<tr>
<td>Bsize</td>
<td>-0.144***</td>
</tr>
<tr>
<td></td>
<td>(4.386)</td>
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<tr>
<td>Bind%</td>
<td>-0.100</td>
</tr>
<tr>
<td></td>
<td>(3.402)</td>
</tr>
<tr>
<td>Duality</td>
<td>-0.015</td>
</tr>
<tr>
<td></td>
<td>(0.559)</td>
</tr>
<tr>
<td>Minority</td>
<td>0.096***</td>
</tr>
<tr>
<td></td>
<td>(3.148)</td>
</tr>
<tr>
<td>Classified</td>
<td>-0.001</td>
</tr>
<tr>
<td></td>
<td>(0.973)</td>
</tr>
<tr>
<td>Assets</td>
<td>-0.075***</td>
</tr>
<tr>
<td></td>
<td>(3.010)</td>
</tr>
<tr>
<td>Q12</td>
<td>0.027</td>
</tr>
<tr>
<td></td>
<td>(0.353)</td>
</tr>
<tr>
<td>ROAA12</td>
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</tr>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Const</td>
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<tr>
<td></td>
<td>(0.161)</td>
</tr>
<tr>
<td>N</td>
<td>1131</td>
</tr>
<tr>
<td>F</td>
<td>6.714***</td>
</tr>
</tbody>
</table>

t-statistics in parenthesis, **** significant at the 1% level, ** at the 5% level and * at the 10% level

In Columns (1) and (2) the variable of interest, F15, the number of females on the board is both positive and significant supporting our expectation that female directorships contribute to good governance.

Other minorities also have a positive effect on the quality of board governance.

Board size and Board independence are significant but not of the expected sign. Eisenberg et. al. (1998) find that board size and firm performance are negatively related. Hermalin & Weisbach (1998) however,
model a firm where good firm performance gives the CEO bargaining power who then uses it to bargain for large boards. Their model predicts a positive relationship between board size and firm performance. Indeed, Yermack (1996) finds results that contradict those of Eisenberg et. al. (1998). Coles et. al. (2008) find that board size is positively correlated to firm size when firms are highly diversified or have high debt ratios.

The portion of independent directors is significantly and negatively related to firm performance. Hermalin & Weisbach (1998) use their bargaining model to predict that good performing CEOs will be able to bargain for less independent boards. Indeed, Baker & Gompers (2003), Ryan & Wiggins (2004) and Boone et. al. (2007) find evidence consistent with the bargaining model.

In tests that are tabulated here we included Institutional holdings. But, consistent with other research (e.g. Ghosh et. al. 2016) there was no relationship between institutional holdings, firm performance, or any other firm characteristic.

Columns 3 and 4 which regress 2012 governance characteristics on the number of female directors in 2015 show that firms that have characteristics associated with good governance will hire more females. All of the independent variables are of the same sign as they will be in 2015. Two additional regressors, Q12 and ROA12 are not significant. Thus we conclude that well-governed firms hire more females and perform better because they do.

Conclusion and Discussion

The present time provides a window of opportunity to view the effect of diversity on the governance of firms. Our research has found evidence that well-governed firms hire more females and perform better because they do.

As more firms add female directors to the board firms female presence will become commonplace and the contribution that females make to firm performance will be more difficult to detect. Moreover, it is not clear that the benefit of having females on the board is because they can contribute from a different skill set of background or if it is simply a matter that firms that include females have drawn their directors from a larger pool of talent. That is a matter for further study.

References


Is There a Change in Correlation between the Chinese and the U.S. Stock Markets?

Robert Blier*, Taylor Provost** and Mark Wu†

November 2016

Abstract
Since the inception of the modern Chinese stock market, the co-movement between the Chinese and the U.S. stock markets has changed over time. We document an increase in correlation between the Shanghai Stock Exchange Composite Index and the Standard and Poor’s 500 Index from 1992—2016. We argue that this change is mainly due to globalization, stronger ties between the two largest economies in the world, and the reduced government intervention in China’s capital markets. This finding also offers a unique and simple long/short investment strategy for active asset management. We show a significant positive return by implementing such a strategy in recent years.

JEL Classification: G10, G11, G12

Keywords: Chinese stock market, SSE Composite Index, S&P 500 Index, long/short
1. Introduction

Recent events such as the Chinese stock market crash in the summer of 2015 and the failure of the circuit breaker policy in January 2016 not only brought turbulence to the Chinese stock market, but also dragged down equity prices in the United States.¹ There is vast literature connecting equity markets of emerging economies to the more developed and mature economies. More specifically, due to a growing number of news headlines in the last decade tying the United States’ and Chinese economies together, the interest in the relationship between their stock markets is increasing. Though previous literature highlights the growing correlation between both economies during highly volatile periods, few studies have looked at the evolvement of their correlation since the inception of the modern Chinese stock markets.

In this paper, we investigate the relationship between the two countries’ stock markets, and document a strengthening correlation between the Shanghai Stock Exchange Composite Index and the Standard and Poor’s 500 (hereafter SSE and S&P 500, respectively) since 1992. While the correlation has been weak and even negative during the early years of the sample period, the correlation steadily increases since the early 2000s. We offer a few explanations as to the drivers of the increase in co-movement of the two markets. Some contributing factors behind the increased correlation might globalization, an increasing number mergers & acquisitions activities, especially the increasing number of Chinese corporations’ mergers and acquisitions of US firms in recent years, as well as the lessening of government intervention in the Chinese capital markets over time.

As an implication from this finding, we implement a simple trading strategy that aims to exploit the correlation results to help retail investors forecast market activity. We construct a portfolio that longs the S&P 500 if the same day return in SSE is positive, and shorts the S&P 500

¹ See Gough (2015) and Bradsher and Tsang (2016).
if the same day return in Shanghai is negative. As our results show, this simple long/short strategy
does not work during the early life of the SSE, but it would yield an average daily return of 0.02%
in 2004—2009 and 0.09% during 2010—2016, they translate to an annualized return of 6.25% and
21.69%, respectively. We compare the results with that of simply buying and holding the S&P
500. We discuss the feasibility of this strategy, including transaction cost and market efficiency
concerns.

The rest of the paper is organized as follows. In Section 2, we review the related literature.
We provide the institutional details of the Shanghai Stock Exchange, and compare with the New
York Stock Exchange in Section 3. In Section 4, we present our data and methodologies. Empirical
results are shown in Section 5. We introduce and test the trading strategy in Section 6, and discuss
related issues and the potential drivers of the correlation we find in Section 7. Section 8 concludes.

2. Related Literature

Literature concerned with correlations between various markets and exchanges of the world
mainly focuses on the United States’ markets and the European markets. Overall, correlations
between international markets have strengthened since the mid-1990s (Loh (2013), Brooks and
Del Negro (2004), Kizys and Pierdzioch (2009)). Previous literature emphasizes several reasons
as to why correlation between different international markets has increased, attributed to an
increase in bilateral trade (Loh (2013), Pretorius (2002)), the stock market bubbles of the late 1990s
(Loh (2013), Brooks and Del Negro (2004)), and financial crises (Loh (2013)).

Previous studies show minimal to no significant correlation between US stock markets and
Chinese stock markets, although the results are mixed. Loh (2013) finds through a study focusing
on the co-movement between 13 Asia-Pacific markets compared with the US and European
markets, and concludes that Chinese stock markets have the lowest correlation of all 13 markets with the US and European markets. Little co-movement is found; however, the co-movement found from 2006 to 2007 shows the dependency to be weak (Loh (2013)). Zhou et al. (2012) find that the volatility of world markets, including the US, does not have great effects on the market volatility of China; nevertheless, after 2005, the Chinese market has increased its effects on other world markets significantly (in terms of volatility spillover), indicating that the influence of Chinese markets on the world increased. Hyde, Bredin, and Nyugen (2007) conclude that the markets of Asia Pacific countries do have a closer relationship to US markets than they do with the markets of European countries. Zhang and Li (2014) find an upward trend in correlation specifically after the 2008 financial crisis, the study’s conclusion is that there is clear evidence that the US close-to-close market returns have influenced the Chinese close-to-open next day market returns, which is similar to the findings presented in this study.

Problems with the varying time scale of trading between US and Chinese markets have been discussed, and corrected in many studies. In a recent study, the wavelet method is used to study market co-movements at various time scales (Loh (2013)). The concern is that investors in different markets are making decisions at various times, which may have an impact when comparing two markets on different time scales (Loh (2013)). The time series problem between markets is of concern in most studies that compare two or more markets on different time scales.

Other previous literature examining the correlation between the United States’ stock markets and more specifically, the Shanghai and Shenzhen stock markets of China, describe weak correlations over the last twenty years, but an increasing impact since 2005. Most studies refer to the period between 2005 and 2007 as a shifting point for the influence of other world markets on Chinese markets, including the United States, and inversely, the influence of Chinese markets on
other world markets. During this time, major financial liberalization and open market policies were implemented in China. The markets of China in the past have been described as segregated but the economy is not (Carpenter et al. (2015)).

3. Institutional Background

The Chinese stock market consists of three main exchanges: The Hong Kong Stock Exchange, the Shanghai Stock Exchange and the Shenzhen Stock Exchange. The Shanghai Stock Exchange (SSE) and the Shenzhen Stock Exchange (SZSE) represent mainland China’s equity market, and combined place the Chinese equity market among one of the largest in the world.

Both the SSE and the SZSE are considered young and, until recently, immature by global standards. After the Chinese economic reform and opening-up in 1978, Deng Xiaoping’s initiatives in China’s capital markets led to the reformation of the SSE and the establishment of the SZSE in late 1990 and early 1991, respectively. These markets are nearly closed to foreign investors although new reforms and programs in recent years, like the Shanghai-Hong Kong Connect, have allowed for more openness across markets. The Chinese stocks are divided into A-shares and B-shares. A-shares are in the local currency (Chinese renminbi, commonly known as yuan) and are open to domestic investors with limitations to foreign investors, while B-shares are traded in US dollars. The Shanghai Stock Exchange is generally comprised of state-backed banks and industrial giants, while the Shenzhen Stock Exchange has many more private companies; more than half of its index is comprised of technology, consumer and healthcare sectors. Despite the youth of these exchanges, both have experienced phenomenal growth since inception with numerous peaks and plunges during the last 25 years, while the Shanghai Stock Exchange is commonly accepted as the flagship stock exchange in China. In Figure 1, we plot the time-series
of the Shanghai Stock Exchange Index from 1992—2016 with the levels of the Standard & Poor’s 500 Index during the same time horizon as a comparison. The S&P 500 is less volatile during the entire sample period and the SSE experiences both severe market growth and decline in 2007 and 2015.

<Insert Figure 1 here>

We provide some institutional details of the Shanghai Stock Exchange and the New York Stock Exchange (NYSE) as a comparison in Table 1, which compares the two exchanges in terms of annual turnover, average daily trading volume, market capitalization, and number of listed companies from 1990—2015. As we can see from the table, the SSE has experienced tremendous growth in the last 25 years: the number of listed companies increased from the original eight to over 1,000; additionally, its market cap grew from 0.3 billion US dollars in 1990 to 4,739 billion US dollars in 2015 (an annual compound growth rate of 47.2%). The market cap of the SSE is now about a quarter of the size of the NYSE.

<Insert Table 1 here>

In addition to the growth in size of the SSE, the improvement in liquidity of the exchange is even more striking as shown in Table 1. The annual turnover has grown from $0.9 billion to $21,370 billion (a growth rate of 52.2%), which is about half that of the NYSE during the last decade, and in 2015 the turnover surpasses that of the NYSE ($21,370 billion vs. $17,536 billion). Furthermore, the average daily trading volume of the SSE surged from 0.02 million shares in 1991 to 42,002 million shares in 2015 (a growth rate of 83.4%) and, during the last decade, is consistently higher than the same statistics of the NYSE. Compared to the United States’ markets, the Chinese stock markets depend much more on individual retail investors while the United States is heavily reliant on institutional investors.
The two countries are connected through means of trade and production despite the poor historic level of correlation between their stock markets. Some studies claim that overseas investors have too small of a share of the Chinese market for there to be any meaningful financial integration. As there is more access to foreign investors, the movements in the Chinese market over time could resemble the markets of other countries, though results supporting this hypothesis are limited.

4. Data and Methodology

4.1. Data

We use the Standard and Poor’s 500 Index (S&P 500) to represent the US and the Shanghai Stock Exchange Composite Index (SSE) to represent China because these indices are the most comprehensive and industry standard for each respective equity market. The S&P 500 Index is chosen to represent the US in the data set because the index is designed best to reflect the overall US market taking into consideration market size, liquidity, industry, and other factors while also mirroring general risk and return of the US large cap market. The SSE Index is chosen to represent China because it tracks all A-shares and B-shares that are part of the Shanghai Stock Exchange and also because it is one of the largest exchanges in China (see Section 3). We obtain index adjusted-close prices from Yahoo Finance, and select data beginning on May 22, 1992. Prior to this date, the SSE stock prices were manually capped at 5%; however, the cap was lifted on May 21, 1992. For the purpose of this paper, we begin our analysis after that day because we look for

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2 It is worth to note that in the United States, the S&P 500 is considered as a strong indicator of the economy because changes in stock prices reflect the future expectations of companies’ cash flows and profitability. However, in China, there seems to be a disconnect between its stock markets and its economy partially because frequent government and regulatory intervention distorts the stock market’s ability to reflect the underlying economy. Nevertheless, the lessening of government intervention and the improvement of the SSE’s quality as an economic indicator is later discussed in Section 7.
real correlation driven by the market, not by fabricated rules. Our sample period ends in January 29, 2016.

Daily-adjusted close prices are used for the calculations of returns to assure that any corporate actions of other forms of distributions that occurred the next day are adjusted for. We include all available market-open dates for each index, resulting in a different number of observations for each index due to differences in holidays. We then calculate the returns from one market day to the next. We plot the actual daily returns of the two indexes in Figure 2, which reveals that the SSE experiences a greater fluctuation of returns while the S&P 500 is more consistent throughout the period; the S&P 500 finds the greatest instability in 2008, during the global financial crisis.

<Insert Figure 2 here>

In order to examine the data more closely and identify changes between the S&P 500 and the SSE over time, the data are broken up into four periods (see Figure 3). These periods are determined purely by splitting the years from 1992 to 2016 in the most numerically even presentation possible while maintaining the same number of years in each period. Each period of the SSE is relatively more volatile when compared to the corresponding period of the S&P 500. For the S&P 500, Period 2 (1998-2003) appears to be the most volatile period, but the end of Period 3 (2004-2009) distinguishes itself as the most volatile period, again due to the global financial crisis.

<Insert Figure 3 here>

Table 2 identifies descriptive statistics of daily returns; measures include maximum, minimum, average, and standard deviation, as well as the number of observations per a particular data set. It is obvious from Figure 2, 3 and Table 2 that the SSE is more volatile than the S&P 500. The maximum and minimum daily returns of the S&P 500 prices occurred during the global
financial crisis (Period 3 (2004-2009)), and the maximum and minimum daily returns of the SSE prices occurred during Period 1 (1992-1997), a period of time when the exchange was just re-launched. In the second half of Table 2, we report the 250-day and the 20-day correlations between these two indexes. Both correlation measures between the two markets begins as a negative number (Period 1 (1992-1997) and Period 2 (1998-2003)), but moves to a positive number (Period 3 (2004-2009) and Period 4 (2010-2016)). Over time, the correlation has strengthened. The average 250-day correlation increased by about 0.08 from Period 2 (1998-2003) to Period 3 (2004-2009) and by about 0.07 from Period 3 (2004-2009) to Period 4 (2010-2016).

<Insert Table 2 here>

We represent the full correlation sample period graphically in Figure 4, while breaking down the data by period in Figure 5. Figure 4 reveals a moderately positive, linear trend line, crossing 0.0 during the year 2003 remaining positive throughout the rest of the sample period. The correlation trend line begins just shy of -0.1 and reaches above 0.1 in the 24 years studied. When the data are divided into the four periods, the data over time show a strengthened correlation (Figure 5). Correlation in Period 1 (1992-1997) and Period 2 (1998-2003) is mostly negative whereas in Period 3 (2004-2009) and Period 4 (2010-2016) the correlation between the S&P 500 and the SSE is mostly positive.

<Insert Figure 4 here>

<Insert Figure 5 here>

1 Different from the returns, the number of observations for correlations is the same for the two indexes’ data time series. Specifically, in calculating correlations, we delete data points where there is only a return from the SSE or there is only a return from the S&P 500, resulting in 5,848 total observations. When constructing the 250-day rolling correlations, there are 5,848-249=5,599 total observations, and 5,848-19=5,829 total observations for the 20-day rolling correlation calculation.
4.2. Methodology

The data set is used to run several regressions between the S&P 500 returns and the SSE returns for the entire data set (1992-2016) and for each of the four designated periods. We have identified, in the previous section, the strengthening co-movement of the S&P 500 and the SSE. The goal in running these regressions is to quantify the magnitude of the increase in correlation between the two indexes over time. We use the results to offer investors a trading strategy to predict the S&P 500 returns for a given trading day by using the SSE returns for the same trading day, which is further laid out in Section 6. In our empirical analysis, we use the following models to identify relationships between the two indexes:

\[ R_{US} = \alpha + \beta R_{China} + \epsilon, \]  
\[ R_{US} = \alpha + \beta R_{China} + D_1 + D_2 + D_3 + \beta_1 R_{China} + \beta_2 R_{China} + \beta_3 R_{China} + \epsilon, \]  

(1) and (2) are the two main models that we employ, and both models use OLS estimations by regressing the daily returns of the S&P 500 on the same daily returns of the SSE. The main reason we use the SSE returns as a regressor for the S&P 500 returns is because the SSE operates ahead of the S&P 500 due to time difference. One could argue reverse causality or endogeneity, but we mainly analyze and identify the correlation rather than trying to explaining the change in one index due to the change of the other. We run five specifications based on (1): for the entire sample period and for each of the four periods. We then run three specifications based on (2): one with year dummies, one with year interactions, and one with both year dummies and year interactions. The total number of observations for regression analysis for the full sample is the same as the number of observations for the previous correlation estimation, 5,848.
5. Empirical Results

In this section, we present and interpret the regression results by executing the model specifications derived from the previous section.

Table 3 presents the regression results, which are organized by the eight different regression model specifications. The coefficient estimates as well as the t-stats in [ ] are reported. In the full sample, the returns of the SSE have a marginally significant effect on returns of the S&P 500 (Specification (1)); an increase in SSE’s daily return of one percent is associated with an increase in S&P 500’s daily return of 4.3 basis points. However, when we break the sample into the four periods, a clear shift of explanatory power is exhibited. The results from the first two periods show inverse and insignificant relationship, while the effect becomes positive and significant in Period 3 (2004-2009), and very significant during Period 4 (2010-2016), during which an increase in SSE’s daily return on one percentage point is associated with an increase in S&P 500’s daily return of 21.1 basis points.

<Insert Table 3 here>

In Model (6), we place year dummy variables into the estimation, allowing individual \( \beta \) estimates while fixing the intercept. There is no statistically significant result from any of the three year dummy variables, indicating a weak year-fixed effect. When we include the year interaction variables into the model, we yield similar results as when regressing the four sub-set of the full sample. In the last model specification (Model (8)), we include both the year dummies and the year interaction terms to show the most comprehensive estimation, and the correlation or effect of predictability is the strongest in Period 4 (2010-2016). Overall, the results from Table 3 demonstrate a correlation that increases over the sample period between 1992 and 2016. We run multi-factor regression models to remove discrepancies and assure that each data set, meaning the
four different periods, have the same intercept. The regressions check for robustness and significance while giving a more precise look at the correlation change overtime.

6. Trading Strategy

Due to the difference of time between the two countries, the Chinese trading day is complete before that same trading day begins in the US. Given that the correlation between the S&P 500 and the SSE strengthens during the tested sample period, we test a simple long/short trading strategy to determine the viability of predicting the S&P 500 daily returns based on the already-completed daily returns of the SSE.

As the SSE yields a positive gain for a particular trading day, the investor will enter an index matching the S&P 500 at the opening price and perform a long investment strategy for the day, and liquidate at the closing price, sitting on cash during the overnight period. Conversely, should the SSE yield a negative return for a given day, the investor will then short an index matching the S&P 500 at the opening price and buy back at the closing price. It is important to note that this paper does not delve into other variables that may affect real returns, varying from daily transaction fees to year-end tax implications. Also, we acknowledge that there are difficulties in effectively implementing this strategy, such as: 1) market efficiency argument - the positive or negative information from the SSE should be already imbedded into the opening price of the S&P 500; we do not get into the trading during outside market hours, but this is an available option for institutional investors (preferably in this case from 8:00 am to 9:30 am before market opens); 2) the selection of and to what extent ETFs and inverse ETFs capture the movement of the actual indexes, and 3) market microstructure concerns that can and to what extent affect investors getting in precisely at market-open and getting out precisely at market-close?
With these imperfections in mind, we construct a simple long/short trading strategy and report the results of investors’ returns in Table 4. The results reflect the plausibility of this trading strategy. We calculate the average, minimum, maximum, standard deviation, overall number of observations for the entire data set as well as for each designated period. We also annualize the returns and standard deviations. Returns are not calculated during dates when one market has a holiday and the other does not. Data displayed in Table 4 aligns similarly with the data revealed in Table 2; as the average 250-day correlation increases, average investor return increases. Average returns begin at -0.01% and -0.05% for Period 1 (1992-1997) and Period 2 (1998-2003), respectively, while increasing to 0.02% and 0.09% for Period 3 (2004-2009) and 4 (2010-2016), respectively. The daily return in Period 4 (2010-2016) translates into an annualized return of 21.69%. Following this strategy results in the most amount of volatility during Period 3 (2004-2009), measured by standard deviation, with a daily measure of 1.35%. On the contrary, the least amount of volatility of the realized returns was during Period 4 (2010-2016), measuring a daily standard deviation of 0.96% (an annualized standard deviation of 15.17%).

<Insert Table 4 here>

The proportion of days when the strategy yields positive (r>0%) or negative returns (r<0%) during the full sample period are 51.1% and 48.8%, respectively. More recent periods have more weights on (r<0%), i.e., when the strategy works. To put the numbers into perspective, we use the passive long-term holding returns of the S&P 500 as the benchmark. During 2010—2016, holding the index yields an average daily return of 0.04% (annual return 10.34%) and an average standard deviation of 1.01% (annual stand deviation of 15.98%). The annual averages of the strategy’s daily returns by year are plotted in Figure 6. The overall positive return is strongly influenced by the superior correlation during the last few years.
7. Discussion

Understanding that the investor return strategy begins yielding positive yearly average returns more consistently after 2005, coupled with the fact that the average 250-day correlation between the S&P 500 and the SSE begins to increase at the beginning Period 3 (2004-2009), we begin to look for the underlying variables that drive this increased correlation.

Throughout the sample period, China has soared in growth categories. As a country, its level of productivity, income, population and more have expanded at extreme rates. Looking at its relationship with the US since the year 1992, China has been both a top five exporter and importer of the US and its foothold has only increased over recent years. Chinese companies have also established partnerships and have become increasingly more aggressive in terms of their merger and acquisition activity with many large US companies.  

China underwent significant changes around the year 2001, a time when the country began its entry into the World Trade Organization (WTO). A series of financial measures demonstrate the efforts in the opening up of its stock market, including the enactment of the Qualified Foreign Institutional Investors (QFII) program in 2012, the Reminbi (RMB) exchange rate reform in 2005, as well as the Qualified Domestic Institutional Investors (QDII) program in 2006 (He (2014)). The year 2007 was a turning point for China’s markets given that China’s full commitment to its WTO financial service liberalization schedule took effect at the end of 2006 (Kwon (2009)). The positive

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4 Gandel of Forbes (2016) reveals that some of China’s largest pending US targets since 2012 include Starwood Hotels ($14.3B), Ingram Micro ($6.3B), GE Electric Appliance Business ($5.4B) and Legendary Entertainment Group ($3.5B). Other large completed Chinese acquisitions of US companies since 2012 include Smithfield Foods ($7.1B), Motorola Mobility ($3.1B), and AMC Entertainment Holdings ($2.6B).
effect of China’s financial liberalization can be seen through the growth of its market in Table 1, as annual turnover, average daily trading volume and market cap all increased by more than 100% between 2006 and 2007. China has also increased its merger and acquisition activity of US companies with respect to number of deals as well as volume since its financial liberalization in 2007.

8. Conclusion

Through analysis of correlation and the use of regression models, it is evident that the S&P 500 Index and Shanghai Stock Exchange Composite Index have become increasingly correlated with each other. Additionally, we find that the ability to use the results of a trading day in China to predict the results of that same trading day in the US is possible. The data suggests that the relationship between the S&P 500 and the SSE from May 22, 1992 to January 29, 2016 has strengthened. We propose that this increased correlation is due to increased market openness, greater cross-investments by these two economies, and less government intervention in the Chinese stock markets.

With the combination of decreased government intervention in the market calling for increased openness for foreign investors, and a larger number of partnerships, acquisitions, and mergers with US companies, the Shanghai Stock Exchange Composite Index has repositioned its relationship with the S&P 500 Index. The data suggests that the correlation between the two has moved from a negative number to a positive number in the last twenty years and is steadily
positive. The events in 2015 concerning both markets have only increased the strength of this theory.\textsuperscript{5}

Understanding that Chinese markets end their trading day before the US market opens for that same day, investors can use information from Chinese markets to predict the outcomes of United States’ markets. While there may be other variables that affect investors’ real returns, such as year-end tax implications and transaction fees, investors can use this information to make more educated investment choices and understand the strengthened relationship of these two economies. This study can be used as a benchmark to help identify relationships between other markets and exchanges; more specifically, the relationship between the United States and China.

\textsuperscript{5} Events such as the 2015 summer market crash in the Chinese stock markets and the more recent 2016 China circuit breaker panic both significantly affected the US markets.
References


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<th>New York Stock Exchange</th>
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<td>Average Daily Trading Volume (million shares)</td>
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Table 2: Daily Returns and Correlations

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<td>20-Day</td>
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<td>0.3077</td>
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This table reports descriptive statistics including average, minimum, maximum, standard deviation, and number of observations for the daily returns of the SSE and the S&P 500, as well as 250-day and 20-day rolling correlations between the two indices. Data are also broken into four mostly evenly distributed periods.
Table 3: Regression Results

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</table>

This table reports OLS regression results of regressing the S&P 500 daily returns on various daily returns of the SSE. Model (1)-(5) use the full data set and the four periods separately. Model (6) uses year dummy variables for the four periods, Model (7) uses interaction variables for the four periods, and finally Model (8) incorporates both year dummies and interaction variables in the same model. *, **, and *** indicate statistical significance at the 90%, 95%, and 99% level, respectively.
Table 4: Investor Returns

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Avg</td>
<td>0.01%</td>
<td>-0.01%</td>
<td>-0.05%</td>
<td>0.02%</td>
<td>0.09%</td>
</tr>
<tr>
<td>(Avg annualized)</td>
<td>3.06%</td>
<td>-1.58%</td>
<td>-13.48%</td>
<td>6.25%</td>
<td>21.69%</td>
</tr>
<tr>
<td>Min</td>
<td>-8.49%</td>
<td>-6.87%</td>
<td>-6.80%</td>
<td>-8.49%</td>
<td>-4.77%</td>
</tr>
<tr>
<td>Max</td>
<td>10.79%</td>
<td>2.81%</td>
<td>5.41%</td>
<td>10.79%</td>
<td>6.59%</td>
</tr>
<tr>
<td>Std Dev</td>
<td>1.13%</td>
<td>0.73%</td>
<td>1.33%</td>
<td>1.35%</td>
<td>0.96%</td>
</tr>
<tr>
<td>(SD annualized)</td>
<td>17.83%</td>
<td>11.54%</td>
<td>20.97%</td>
<td>21.31%</td>
<td>15.17%</td>
</tr>
<tr>
<td># of Obs</td>
<td>5848</td>
<td>1418</td>
<td>1508</td>
<td>1485</td>
<td>1437</td>
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<tr>
<td># of Obs (&lt;0)</td>
<td>2855</td>
<td>718</td>
<td>767</td>
<td>693</td>
<td>677</td>
</tr>
<tr>
<td># of Obs (&gt;0)</td>
<td>2987</td>
<td>696</td>
<td>741</td>
<td>791</td>
<td>759</td>
</tr>
</tbody>
</table>

This table reports the results of implementing the simple long/short trading strategies: long at the opening price of S&P 500 and liquidate at the closing price if the return of SSE on the same day is positive, or short at the opening price of S&P 500 and buy back at the closing price if the return of SSE on the same day is negative. Descriptive statistics (daily) - average, minimum, maximum, standard deviation, and number of observations are reported, as well as the annualized averages and standard deviations. The frequency counts and the proportions of days when the strategy yields a negative (<0) and a positive (>0) returns are also reported. Data are broken into the four periods.
Figure 1: Daily Prices of SSE & S&P 500 (1992-2016)

The dark line and the left scale reflect S&P 500’s prices and the light line and the right scale reflect the SSE’s prices between May of 1992 and January 2016.
Figure 2: Daily Returns of SSE & S&P 500 (1992-2016)

Figure 2 depicts the daily-adjusted returns of the Shanghai Stock Exchange Composite Index (left) and the Standard and Poor’s 500 (right) between May 22, 1992 and January 29, 2016.
In this figure, we plot the returns of the SSE and the S&P 500 broken down by period.
Figure 4: 250-Day Correlation between SSE & S&P 500 (1992-2016)

In this figure, we plot the 250-Day correlation between the SSE and the S&P 500. The plot also displays the trend line of best fit.
Figure 5: 250-Day Correlation by Period between SSE & S&P 500

In this figure, we plot the 250-day correlation between the SSE and the S&P 500 by period.

Period 1 (1993-1997)


Period 3 (2004-2009)

Period 4 (2010-2016)

In this figure, we plot the 250-day correlation between the SSE and the S&P 500 by period.
In this figure, we plot the annual average of daily returns through the use of the long/short trading strategy during the entire sample period (1992-2016).
ABSTRACT

Systematic traders employ fully systematic strategies to manage their investments. Due to defined, algorithmic strategies, it is possible to determine investor responses to any set of market conditions. Consequently, sensitivity analysis can be conducted to uncover undesirable strategic behavior and enhance strategy robustness by adding controls to reduce or increase exposure, depending on the market. Here, we formulate a simple systematic trend-following strategy (i.e., trading model) to simulate investment decisions and a market model to simulate the evolution of instrument prices. We then map the relationship between market model parameters and strategy performance under a particular set of trading model parameters to explore the sensitivity of the strategy to different market conditions. The sensitivities derived provide an effective set of metrics for determining the fundamental profile of the simple trading strategy and suggest an explanation for the functions of trading model components commonly found in trend-following strategies.

Keywords: finance, trading, markets

1 INTRODUCTION

For the class of market participants employing fully systematic approaches to manage their investments, it is possible to determine the exact responses of their strategies to any conceivable set of market conditions. As a result, they can conduct sensitivity analysis to systematically uncover undesirable strategy behavior and enhance strategy robustness.

Systematic traders generally use sensitivity analysis to identify the set conditions under which the system will operate within acceptable bounds. In the this paper, we refer to this set of conditions as the operational domain of the strategy (for a specific set of trading model parameters). The broader the spectrum of market conditions over which a trading system can perform within acceptable performance bounds (i.e. the broader the operational domain of the strategy), the more robust the system.

In general, the operational domain of a trading strategy can be broadened through the introduction of feedback and feed-forward risk controls. Feedback risk controls operate to reduce the impact of unpredictable phenomena or events on strategy performance, while feed-forward controls exploit regularities in market structure to make local predictions that aid in the enhancement of strategy performance. We use feedback controls when poor trading performance is not driven by something we can predict. We use feed-forward controls when we understand the drivers of poor performance and there is enough persistence in the market conditions for us to effectively anticipate future poor performance.
In the following sections, a simple systematic investment approach - a so called trend-following strategy – is explored through the use of Monte Carlo simulation. In particular, a market model is specified and used to generate realistic realizations of financial instrument prices across of broad spectrum of market conditions. Sensitivity analysis is then conducted, mapping the relationship between market model parameters and the strategy performance under a particular set of trading model parameters.

The market model (i.e., the model used to simulate instrument prices) has been designed to capture a set of essential stylized facts believed to be critical to the effective functioning of the strategy. As a model is a simplification of reality by definition, we do not attempt to reproduce all empirical stylized facts. We also limit the complexity and scope of the work by focusing on the instrument-level strategy. Portfolio-level meta-strategies that determine how to allocate across instrument-level strategy instances are not explored.

2 LITERATURE REVIEW

There exists a vast literature on the empirical characteristics of financial markets, documenting extensively the basic stylized facts. A similarly broad literature also exists on the derivation of financial derivative sensitivities. To price and risk manage products with path-dependent payoffs similar to a trend-following strategy, simulation is often required. Despite a seemingly obvious link between the analysis of systematic trading strategies and the analysis of replication strategies used to manufacture financial derivative products, little published work exists leveraging the findings in these two areas of research to the analysis of systematic trading strategies. Although the scope of this paper does not allow for a detailed exploration of the stylized facts, a number of comprehensive surveys exist, including work by Bollerslev et al. (1992), Brock & Chou (1995), Campbell et al. (2014), Cont (2001), Farmer & Geanakopolis (2009), Pagan (1996), and Shephard (1996). The most basic and commonly agreed upon facts upon which we rely in this paper are as follows: 1) Price returns of financial instruments show insignificant serial correlation; 2) The unconditional distributions of returns are heavy-tailed, and; 3) Price variability for all financial instruments is both time-varying and serially dependent.

3 METHOD OVERVIEW

Typically, systematic traders backtest the strategies that they employ (i.e., they use historical data to evaluate potential performance). Such backtesting allows systematic traders to determine the response of a strategy to the exact mix of market conditions that actually occurred, but not the response of a strategy to conditions that have not yet occurred or that may occur in different proportions in the future. Typically, the longer the historical period used, the more varied the market conditions, and the more likely that historical data can be used to build a relatively complete picture of the operational domain.

There are two main ways to supplement the historical data available for testing, namely market model-based Monte Carlo simulation, and Monte Carlo resampling. In this paper, we focus on the former approach to explore the characteristics of a simple trend-following strategy. In order to simulate financial prices, a market model is designed, implemented, and calibrated to financial market data. The market model reproduces key well-established stylized facts, particularly focusing on time-varying, serially dependent price variability. Trading strategy sensitivities are created by simulating price scenarios - consisting of many realizations - for a range of key market model parameters, then computing the performance of the trading strategy for all realizations under each scenario.

In the following sections, we provide overviews of the data acquisition and transformation process, the trading model, and the market model used in later sections of the paper to generate sensitivities.
4 DATA ACQUISITION AND TRANSFORMATION

Prices, dividends, and corporate actions for each of the constituents of the S&P500 index over the period between 2000-01-01 and 2016-11-30 were acquired from Bloomberg. For each instrument that existed over the entire period, a volatility-normalized total return index accounting for changes in prices, accrued dividends and corporate actions was constructed, meeting the terms of the data use agreement (Figure 1).

The index for each instrument represents the total return on a quarterly re-balanced position sized to equate a move of 3 units of price variability (i.e., average true range) to a 1% loss. Use of the volatility-normalized total return index facilitates comparison of model parameters across the instrument universe.

5 TRADING MODEL

We implement a very simple version of a common systematic trend-following strategy as detailed by Faith (2007). The instrument level logic of the trading system has a several core components: 1) The entry signal, determines timing for initiating a position (either long or short) in a particular instrument; 2) The position sizing algorithm determines the size of the position; and, 3) The trailing stop loss determines the timing of an exit from the position.

Both the position size and the distance of the trailing stop from the current price level are functions of the true range, $R_t$, a commonly used measure of the daily price range of a financial instrument that accounts for gaps from the close of the previous period to open of the current period.

$$R_t = \max\{P_{n\text{H}} - P_{n\text{L}}, \ \text{abs}(P_{n\text{H}} - P_{t-1}), \ \text{abs}(P_{n\text{L}} - P_{t-1})\}$$
In this equation, \( P_t H \) and \( P_t,L \) are the current daily high and low prices respectively, and \( P_{t-1} \) is the previous close price.

Filters are commonly used to smooth price series. We use exponentially weighted moving averages (EMAs) to smooth both price and the true range time series. The core rules of our simple trading model are detailed briefly in the next two sub-sections.

### 5.1 Long Position

At time \( t \), if the fast \( EMA_{t-1,F} \) is above the slow \( EMA_{t-1,S} \) and we have no position, we enter a long position of \( p_t \) units, where \( p_t \) is as follows.

\[
p_t = \frac{(f \times A_{t-1})}{\max[ATR_{t-1} \times M, L]}
\]

Here, \( f \) is the fraction of account size plus accrued realized profit and loss, \( A \) is the amount risked per bet, \( ATR_{t-1} \) is the EMA of the true range for the previous time step, \( M \) is the risk multiplier, and \( L \) is the \( ATR \) floor.

We set our initial stop loss level \( M \) units of \( ATR \) below the entry price level, \( p_t \). For each subsequent time, \( t \), we update our stop level as follows: \( s_t = \max[P_t - ATR_{t-1} \times M, s_{t-1}] \). We exit our long position if the price, \( p_t \), moves below the stop loss level, \( s_{t-1} \).

### 5.2 Short Position

At \( t \), if the fast \( EMA_{t-1,F} \) is below the slow \( EMA_{t-1,S} \) and we have no position, we enter a short position of \( p_t \) units.

\[
p_t = -\frac{(f \times A_{t-1})}{\max[ATR_{t-1} \times M, L]}
\]

We set our initial stop loss level \( M \) units of \( ATR \) above the entry price level, \( p_t \). For each subsequent time, \( t \), \( S_t = \min[P_t - ATR_{t-1} \times M, S_{t-1}] \).

Regardless of whether we are long or short, for each trade we budget for a loss of \( f \) percent of our account size plus accrued realized P&L. The effectiveness of this crude risk budgeting system is a function of the characteristics of the true range. Serial dependence in the true range can transform this simple mechanism from a feedback control to a feed-forward control.

### 6 Market Model Specification and Calibration

We define and use a simple discrete time model to simulate a broad set of market conditions. Each scenario consists of realizations of both price and true range.

The following discrete time process is used to generate price realizations for a single stock.

\[
P_t = P_{t-1} \exp(\mu \Delta t + \sigma_t \epsilon_t)
\]

Here, \( t = 1 \ldots T, \Delta t = 1/T, \epsilon_t \sim N(0, 1) \), \( \mu \) is the constant annual drift for the instrument over time period, \( T \), and \( \sigma_t \) is the volatility based on true range, defined as \( \sqrt{\pi B \times R_t} \) (see Brunetti & Liholdt, 2007). Following Lunde (1999), Brunetti & Liholdt (2007), and Chou (2005), the true range is modeled according to a CARR(q,p) process, \( R_t = \lambda_t \delta_t \). Here, \( \lambda_t = \omega + \sum_{i=1}^{q} \alpha_i R_{t-i} + \sum_{j=1}^{p} \beta_j R_{t-j} \) is the conditional mean range at time \( t \) and \( \delta_t = R_t / \lambda_t \) is gamma distributed. The coefficients \( \omega, \alpha, \beta \) in the conditional mean formula are all positive to ensure that \( \lambda_t \) is positive. Our model has two sources of
uncertainty, $\epsilon$ and $\delta$. Bursts in volatility driven by the true range process can generate price momentum that looks very similar to that observed in real markets. And simulating this bursts is then trivial.

For each instrument in the universe under study, we fit a CARR(1,1) model with a gamma-distributed error. We then use the cross-section of parameters to define the starting range of parameters for use in our sensitivity analysis.

The first row of Figure 2 was derived by computing the autocorrelation functions (ACFs) for the log returns, absolute value of the log returns, and the true ranges for each instrument in the universe under study, then computing the median and 95% confidence interval. The second row shows the autocorrelation of the standardized log returns, the absolute value of the standardized log returns, and the conditional true range based on the calibrated model. The last row shows the median and 95% confidence interval for the standardized log return, the absolute value of the standardized log return and the true range for a for 1000 realizations generated for a sample instrument using the market model. Notice that the standardized residuals of the fitted model show little autocorrelation across all instruments in the sample, indicating that the model accounts reasonably well for serial dependence in-sample. The shape of the ACF for the simulated true range, however, shows a faster decay than that observed in practice. It is apparent from the difference in the actual and simulated ACF that a model based on an underlying long-memory process may provide a better fit than the short-memory process chosen.
7 SENSITIVITIES

7.1 Sensitivity Analysis for Parameters

In the previous section, we specified a market model, then calibrated it to each instrument in the equity universe under study. In this section, we create sensitivities by simulating price scenarios for a set of market model parameters and computing the performance of the trading model under each scenario.

The parameter space of the combined market and trading models is vast. To reduce the dimension of the problem, an initial study was conducted to coarsely explore the impact of different trading model parameters on the strategy backtest results. A set of trading model parameters was selected from stable areas of the response curves.

Following the selection of the trading model parameters, the range of market parameters observed over the entire instrument universe under study was examined and used to determine realistic starting parameter ranges for sensitivity analysis. These ranges were then extended to account for realistic conditions that may be observed in the future. Once ranges were selected, another coarse study was conducted to determine which market model parameters had the largest impact on performance. Based on these results, parameters $\mu$, $\omega$, $\alpha$, $\beta$ were selected for the sensitivity analysis. The strategy performance used was terminal wealth relative or TWR (Vince, 2007). We used 1000 paths, each with a 1250 day length (roughly 5 years), for all simulations. Seeds were saved for replication.

7.2 Sensitivity Analysis for Trend

Trend-following strategies operate on premise that the emergence of a trend in a particular instrument cannot be predicted. The system is designed to maintain a position in an instrument as long as it is trending and exit the position when the trend has reversed beyond $M$ times the typical daily range. Any predictability in the characteristics of true range, is thus expected to enable strategy enhancement.

First we use our market model defined above to determine the sensitivity of the strategy to trends of different magnitudes by computing trading model performance under different drift rates ($\mu$) (Figure 3).

![Figure 3. Trading Model Performance Sensitivity to Changes in Trend](image-url)
The profile that emerges from this sensitivity analysis of the strategy performance with respect to changes in the drift illustrates the essence of the strategy. From the profile, it is clear that as the price moves up or down strongly, the strategy performance increases. The less variability around the trend, the better the strategy performance. Choppy, sideways movement in prices produces a condition where the strategy repeatedly enters and gets stopped out, generating losses for roughly half of the paths.

By holding both the trading model parameters and the $\alpha$ and $\beta$ parameters of the market model constant, and perturbing the $\omega$ parameter of the market model up or down, we determine the impact of changes in variability for the same drift scenarios previously (Figure 4).

[Figure 4. Trading Model Performance Sensitivity to Changes in Trend Under a Reduction in General Level of Variability]

Decreasing the $\omega$ parameter roughly 50% to the lower end of the range observed across all of the instruments in the universe under study (i.e., roughly the 1st percentile), we see the profile steepen and shift up – a marked improvement in performance.

### 7.3 Sensitivity Analysis for Volatility

Given the observed serial dependence in the true range, a natural question arises as to the sensitivity of the performance of our simple trading model to the strength of autocorrelation. To determine the link between strategy performance and autocorrelation we perturb the $\alpha$ and $\beta$ parameters along the line depicted in Figure 5, generate price and true range scenarios, then evaluate strategy performance under each scenario.
CONCLUSIONS

In this paper, we formulated both a simple systematic trend-following strategy (i.e., trading model) to simulate investment decisions, and a market model to simulate the evolution of instrument prices. We explored the sensitivity of our strategy to different market conditions (for a particular set of trading model parameters) and provided a map between the market model parameters for each scenario representing a particular market condition and strategy performance. In particular, we focused on identifying the performance impact of changes in 1) serial dependence in price variability, and 2) changes in the trend.

The sensitivities derived provide an effective visual depiction of the fundamental profile of the simple trading strategy and suggest an explanation for the functions of trading model components commonly found in trend-following strategies. The serial dependence in the true range appears to enhance strategy performance, particularly during periods of strong performance, by reducing conditions under which the strategy enters and exits repeatedly from a sideways moving market. Our simple model suggests that a slightly more complex feed-forward controller could be created to further improve performance of the strategy.

An extension of our simple single instrument market model to a multiple instrument model could provide useful sensitivity analysis relating to the cross-dependence between instruments. Incorporation of long range dependence into the true range piece of the market model would also allow us to improve the realism of our results.
REFERENCES


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UNDERSTANDING ASSET PRICING ABNORMALITIES: A LATENT VARIABLE MODEL APPROACH

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This project will use Latent Variable Modeling to examine a number of factors and assess their relation to a stock market asset bubble formation. This study will define an asset bubble as based on the variance of the earning/price multiple, looking at both the Dow Jones Industrial Average and the S&P 500. The construction of the LVM will include several Macroeconomic measures for the independent variable (state of the Macroeconomy) and three mediators which will be latent variables of the business environment, the consumer, and the credit market. Several different studies will be conducted, including a total sample and a smaller series of studies which will compare the results by decade.
Which Analysts’ Recommendations Should We Trust? - Developing an Effective Strategy in the Portfolio Management Practice

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Abstract

This paper investigates the effectiveness of the analysts’ recommendations and it contributes to the existing literature by exploring the connection between the short-term effectiveness and the long-term effectiveness. The short-term effectiveness is examined through the event analysis of the abnormal return for the recommended stock around the announcement, and the long-term effectiveness is examined through the investment value from a passive portfolio management strategy. The findings in this paper confirm that both short-term and long-term effectiveness are statistically significant, and the effectiveness based on the change of the recommendation rating is stronger than the effectiveness based on the pure recommendation rating. The analysts’ recommendations effectiveness is found to be temporal. The exploration of the connections between the long-term investment value and the short-term market reactions is performed by comparing the performance of the portfolios that use the recommendations as trading signals in different ways. The result indicates that conditional investment decision based on the short-term effectiveness at individual recommendation level does not improve the portfolio performance. However, at the level of individual analysts, the portfolio profitability can be improved by following analysts with superior historical performance.

Keywords: Analyst Recommendations, Event Analysis, Conditional Investment Choice, Portfolio Construction
1. Introduction

The extant literature finds that analysts’ recommendations contain important information that affects the stock prices (B. M. Barber, Lehavy, & Trueman, 2010; Dhiensiri, Mandelker, & Sayrak, 2005; Jegadeesh & Kim, 2006), therefore analysts’ recommendations are associated with significant market reaction and provide informative value to the covered firms. As analysts’ recommendations are one of the most important services that financial institutions provide to the investors, those recommendations should also carry investment value for the investors to make profit. There are evidences showing that analysts do provide profitability and investment value (B. Barber, Lehavy, McNichols, & Trueman, 2001; Jegadeesh & Kim, 2006; Womack, 1996). However, it still remains unclear whether there exists a strong correlation between the investment value and the informative value of the analysts’ recommendations.

The major reason that accounts for the rarity in the study of the relationship between the informative value and investment value of the recommendation is the difference between the commonly adopted methodologies in the examination of the two types of recommendation values. The informative value is typically examined through then event analysis, which focuses on the average effects in a group of recommendations and determines whether a certain type of recommendation is associated with statistical significant average abnormal returns (Kothari & Warner, 2004). The event analysis usually takes a short-term horizon around the announcement of the recommendations to calculate the abnormal return and produces less reliable result in a long-term horizon (M. Y. Chen, 2014). Therefore it is not suitable for measuring the long-term investment value of the recommendations. To examine the investment value that accounts for the profitability of the recommendations in a long-term horizon, the portfolio construction approach is preferred by some researchers (B. Barber et al., 2001; B. M. Barber et al., 2010; Jegadeesh &
Kim, 2006). The portfolio construction approach designs a portfolio management strategy that follows the trading rules based on the information of recommendation levels or recommendation changes, and then evaluates the performance of the constructed portfolio. Since the portfolio construction approach and the event analysis approach are very different to each other and there lacks a uniformed method to investigate both the informative value and the investment value together, previous research generally does not address the relationship between the two types of values.

This paper aims to explore how much investment value can be potentially added to the investors’ portfolio management activity, given the information of the stocks’ short-term informative value to the recommendation announcement. Therefore, this paper bridges the gap in the extant research by linking the investment value and the informative value together and offers a conceptual breakdown of the added-value for the analysts’ recommendations. This paper employs the IBES database and focuses on US sell-side analysts in the analysis. The analysis begins with the examination of the informative value through a conventional cross sectional event analysis. The abnormal return of stocks subsequent to each recommendation is calculated and statistical tests are performed to determine whether a certain type of recommendations is associated with significant average market reactions. Based on both the pure recommendation ratings and the change of the recommendation ratings, the event analysis result shows that analysts’ recommendations are overall influential and associated with a significant abnormal return. Then this paper incorporates the result of the abnormal return in the event analysis into the examination of the investment value in the portfolio construction approach. In particular, the analysis in this paper considers the performances of the portfolios that follow different passive investment strategies and conceptually describes the incremental value added due to the
incorporation of the additional information about the analysts’ recommendations. The first portfolio (Portfolio A) assumes that the investors blindly follow analyst’ recommendations when the recommendations become available. As the result, Portfolio A obtains an annualized abnormal return of 7.33% for a rating-based strategy and an annualized abnormal return of 13.94% for a revision-based strategy. The specified holding period for each stocks remaining in the portfolio and the delayed actions in making the transactions are also considered. The results show that the abnormal return diminishes as the stock holding period increases and the length of the period of delay increases. If the investment decisions are delayed by more than 3 days since the observation of the announcement, the portfolio does not exhibit any significant abnormal return, which indicates that the nature of the analysts’ overall informative value is temporal. The second portfolio (Portfolio B) examines whether the loss due to the delayed actions can be compensated by the gain of the information about the market reaction during the delayed period. The portfolio is designed by assuming that investors make the investment decision conditional on the observed short-term abnormal return following each announcement. For both rating-based strategy and revision-based strategy, sub-portfolios are constructed by a) following recommendations with effective/ineffective market reaction (the sign of the abnormal return is consistent with the expected direction is assumed to be effective, otherwise ineffective), b) following recommendations with different quintiles for the magnitudes of the abnormal return according to the expected direction. The performance evaluation on the Portfolio B and its sub-portfolios demonstrates that none of these strategies produces significant abnormal return, therefore at the individual recommendation level, most of the analyst’ recommendation value can only be attributed to the short-term market reaction (informative value) but not the long-term profitability (investment value).
The last portfolio management strategy (Portfolio C) acknowledges the temporal property of the short-term informative value and avoids the delayed actions in following analysts’ recommendations. Instead, it assumes that investors only adopt recommendations from reliable analysts. In this strategy, two measurements of the analysts’ historical recommendation performance are considered. One is based on the proportion of effective predictions in all previous recommendations, and the other is based on the average of the informative values for all previously issued recommendations. Similarly to Portfolio B, sub-portfolios are also constructed based on the quintile of the historical recommendation performance from the both measurements. As the result of filtering the analysts with reliable and trackable record, Portfolio C outperforms Portfolio A in terms of the abnormal return by 5% annually across all different holding period. The examinations of the sub-portfolios reveal that the profitability for each sub-portfolio is substantial and is in positive relation with the previous performance at the analyst’s level. Therefore, the analysts’ consistent capability of generating the informative value serves plays an intermediate role that links the informative value and the investment value.

The rest of the paper is organized as follows: Section 2 reviews the literature, Section 3 conducts the event analysis to examine the informative value, Section 4 performs the portfolio construction analysis to explore the relationship between the informative value and the investment value, Section 5 concludes.

2. Related Literature

The informative value of analysts’ recommendations has been widely studied by many researchers. As mentioned earlier, the cross sectional event analysis is the most common approach for the examination. Stickel (1995) measures the average price reaction to the changes
in individual analysts’ recommendations for the US stocks. He documents the findings that the short-term price change is related to the strength of the recommendation, the change of the recommendation, and the analysts’ reputation, brokerage size, and contemporaneous earnings forecast revisions. Womack (1996) performs the similar analysis at the brokerage level, and he further discovers that new added-to-sell recommendations contains more predictive power than the new added-to-buy recommendations. Jegadeesh and Kim (2006) examine the informative value of analysts’ recommendations across G7 countries. Through the event analysis framework, they find that the US analysts achieve superior performance in generating the abnormal return and creating more trading volume around the announcement than those of foreign analysts in the same sample. Using the Fama-Macbeth procedure to examine the cross-sectional regression of the abnormal return, they find that both size and book-to-market ratios are negatively related to the market reaction of the recommendation revisions for both US analysts and non-US analysts.

Brown, Chan, and Ho (2009) study the Australian financial market and they find that the short-term market reactions to the changes of the individual recommendation ratings is stronger than that to the difference between the individual ratings and the consensus ratings. Using a [-1, +1] event window, they show that the informative value is influenced by the analyst’s reputation, and the divergence of the analysts’ opinions. The recommendations issued to stocks listed on NASDAQ have an overall greater impact on the price change than the stocks listed on the NYSE or AMEX, since less information is available on NASDAQ-listed stocks which makes the analysts’ recommendation to contain more informative value. Clarke, Khorana, Patel, and Rau (2011) find that analysts from affiliated investment banks, analysts from unaffiliated investment banks, and analysts from independent non-investment bank firms all issue fewer strong buys after the adoption of the Global Settlement, which is designed to separate investment banking
and equity research. Moreover, the independent analysts’ upgrades are significantly less informative than the updates issued by the other two types of analysts, and the results persist after controlling for the analysts’ experience, all-star status, and brokerage size. Murg, Pachler, and Zeitlberger (2014) also employ the event analysis to study the stocks listed in the Austrian market, and they show that increasing the complexity of the market model in the event analysis does not change the result when compared to a simple market model such as traditional CAPM. 

DONG and HU (2016) compare the stock market response to the recommendations issued during weekdays with those to the recommendations issued in the weekend. They find that NYSE Rule 472 and NASD Rule 4711 increase the probability of observing a weekend sell, and the sell recommendations issued in the weekend have larger price drift than those issued in the weekday.

The investment value of analysts’ recommendations is often assessed from an implementable investment perspective and the portfolio construction approach is more appropriate to measure such an investment value. B. Barber et al. (2001) examine the portfolio based on the consensus recommendations with US data. The portfolios are constructed by first sorting stocks based on the consensus level, then using a value-weighted strategy to buy the most favorable stocks and sell the most unfavorable stocks. This investor-oriented perspective allows the researchers to examine whether the generation of abnormal return is still significant net of the trading costs. In addition to the consideration of transaction cost, they also examine the impact of the delays in the trading action and frequency of the rebalancing. They find that a less frequent portfolio rebalancing and a delayed reaction to the recommendation changes diminishes the portfolio profitability. Jegadeesh and Kim (2006) construct similar consensus-based portfolios to investigate the profitability of following G7 analysts. However they find that none of the portfolio strategies was profitable in any countries for their sample. However, when the trading
strategy is changed to be revision-based instead of consensus-based, they find that following US analysts can generate highest profit, then followed by Japan. They also discover that holding the stocks longer and increasing the delays has the effect of reducing the abnormal return of the portfolio. Without the consideration of the transaction cost, they perform the comparison between a value-weighted strategy and an equal-weighted strategy. Their result show that the value-weighted abnormal return are generally smaller than equal-weighted return. However, for market that contains small firm segment, the value that analysts add is not affected by the firm size. B. M. Barber, Lehavy, and Trueman (2007) construct portfolios based on the analysts’ types and the recommendation level. Through the comparison of the portfolio performance, they discover that the daily abnormal returns of the portfolio by the independent research firm buy recommendations outperform that by the investment bank analysts. They attribute this difference in the profitability to the fact that investment bank analysts are more prone to be compromised in their research due to the conflicts of interest in the underwriting relationship. Casey (2013) applies the same strategy as proposed by B. M. Barber et al. (2007) but uses samples that cover different period. Her findings indicate that the investment banking recommendations seem to offer superior in spite of the potential underwriting and trading-based conflicts.

3. Data, Sample and Recommendation Informative Value

This section presents the descriptive statistics of the data that has been used in this paper, and it also displays the result of recommendation informative value from the event analysis approach. The next paragraph begins with description of the data.

Descriptive Analysis

The data employed in this paper is obtained from IBES database. IBES database applies a 5-point scale to describe the recommendation rating level. In the original record, 1 denotes
“Strong Buy” the highest favorable rating, and 5 denotes highest unfavorable rating. This paper reverses the numeric rating to keep aligned with the notation used in other literature. As the result, 1 denotes “Strong Sell”, 2 denotes “Sell”, while 5 represents “Strong Buy” and 4 is “Buy”, 3 indicates a neutral “Hold”. The sample period covered in the analysis is from Jan-1998 to Dec-2015. The analysis only focuses on the US stocks, and it excludes records that do not have a valid CUSIP code for the recommended stock and records that do not have an identifiable analyst. To ensure that the stocks analyzed have a coherent recommendation history, stocks that have not been recommended since 2003 are also excluded. In the cases that an analyst revises his/her rating on a specific stock several times during the same date, only the last recommendation is kept. In accordance with previous literature, the recommendations employed in this paper are re-classified in terms of the revision type on the level of individual analyst. If an analyst does not provide any rating for a specific stock for 360 calendar days, then it will be treated as the analyst drops the coverage on that stock. As the result, if there is no preceding rating on the same stock by the same analyst, or the preceding rating has been more than 360 days old, then that recommendation will be coded as “Initiation”. If the preceding rating is considered to be outstanding and the level of the rating remains the same, then that recommendation is coded as “Reiteration”. Lastly, if the current rating is higher than the preceding rating toward the favorable rating, then that recommendation is coded “Upgrade”; otherwise it will be coded as “Downgrade”. As the result of this classification, the final data contains 379,977 individual recommendations, collected from 4,003 stocks and 12,991 different analysts.

Table 1 presents the frequency distribution of these recommendations. Previous literature (B. M. Barber, Lehavy, McNichols, & Trueman, 2006; Chan, Lo, & Su, 2014; C.-Y. Chen &
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Chen, 2013) documents the finding that analysts tend to exhibit over-optimism when writing recommendations, therefore there are more “Strong Buy/Buy” recommendations than “Sell/Strong Sell” recommendations. About 50% of the data employed in this paper comprises “Strong Buy” or “Buy”, while only about 8.4% of the records are “Strong Sell/Sell” recommendations, which confirms the prevailing over-optimism. Based on the classification of recommendation revision, there are about 51.1% “Initiations”, 10.2% “Reiterations”, 18.6% “Upgrades” and 25.4% “Downgrades”.

**Recommendation Informative Value from Event Analysis Approach**

The informative value of the analysts’ recommendation is examined through the event analysis. In this paper, a [-1, +T] trading day window is used to calculate the abnormal return around the recommendation announcement for each category of recommendations, with day 0 being the announcement date. Both the cumulative abnormal return (CAR) and the buy-and-hold abnormal return (BHAR) are calculated as follow:

\[
CAR_k(T) = \frac{1}{T+2} \sum_{t=-1}^{T} AR_{k,t} = \frac{1}{T+2} \sum_{t=-1}^{T} (R_{k,t} - R_{k,t}^{BENCH})
\]

(1)

\[
BHAR_k(T) = \prod_{t=-1}^{T} (1 + R_{k,t}) - \prod_{t=-1}^{T} (1 + R_{k,t}^{BENCH})
\]

(2)

where \(AR_{k,t}\) is the daily abnormal return of event \(k\) on date \(t\), \(R_{k,t}\) is the daily stock return of the event \(k\) on date \(t\) in the defined event window, and \(R_{k,t}^{BENCH}\) is the benchmark portfolio return. This paper adopts the Carhart Model (Carhart, 1997) to calculate the benchmark return. Equation (3) specifies the formula for the calculation.

\[
R_{k,t}^{BENCH} = \beta_1 (R_{mkt} - r_f) + \beta_2 * SMB + \beta_3 * HML + \beta_4 * MOM + \alpha + r_f
\]

(3)

\(R_{mkt}\) is the rate of return for the market portfolio as given by the CRSP value-weighted market index, and \(r_f\) denotes the risk-free asset rate of return as given by the yield of one-month
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Treasury bill. $SMB$ is the difference between the return on the portfolio of “small” capitalized stocks and “big” capitalized stocks, $HML$ is the difference between the return on the portfolios of “high” and “low” book-to-market stocks, and $MOM$ is the difference between the return on portfolio of past one-year “winners” and “losers". The parameter $\alpha$ represents the excess return for the underlying asset, and parameter $\beta$ denotes the sensitivity to each factors. A [-60, -15] trading day window is the estimation period to run the regression for the Carhart Model and obtain the estimate of $\beta$s and $\alpha$. The next [-14, -2] trading-day window serves as the gap between the estimation period and the event window, which reduces the potential bias in the event analysis (Kothari & Warner, 2004). This paper employs the Patell’s $Z$ test (Patell, 1976), and cross sectional $t$-test to examine the statistical significance of the average abnormal return for each category of the recommendations. Patell’s $Z$ is used to test $H_0: AR_t = 0$, and $z_{Patell, CAR}$ is used for testing $H_0: CAR = 0$; and cross sectional $t$-test is used to test $H_0: CAR = 0$ and $H_0: BHR = 0$. The following two formulas present the calculation of the Patell’s $Z$.

\[
Z_{Patell, ARt} = \frac{\sum_{k=1}^{M} SAR_{kt}}{\sqrt{\sum_{k=1}^{M} \frac{S_k - p - 1}{S_k - p - 3}}}
\]  

(4)

\[
Z_{Patell, CAR} = \frac{\frac{1}{M} \sum_{k=1}^{M} SCAR_k}{\frac{1}{M} \sqrt{\sum_{k=1}^{M} \frac{S_k - p - 1}{S_k - p - 3}}}
\]  

(5)

where $M$ is the total number of recommendations within the sub-category, $SAR$ is the standardized $AR$, $S_k$ is the number of non-missing return observations in the estimation period of event $k$, $p$ is the number of explanatory variables used in the benchmark regression model, and

---

1 For detailed definitions, see (Carhart, 1997).
SCAR is the standardized CARs that account for the model induced variance. In the case of Carhart model, \( p \) equals 4. The calculation of SAR and SCAR is specified as follow:

\[
SAR_{kt} = \frac{AR_{kt}}{\sqrt{Var(\epsilon_{AR_k})}} \tag{6}
\]

\[
SCAR_k = \frac{CAR_k}{N_k \cdot \sqrt{Var(\epsilon_{AR_k})}} \tag{7}
\]

where \( \epsilon_{AR_k} \) is the residual from the model estimation in event \( k \), and \( N_k \) is the window length of event \( k \).

Equations (8) to (10) provide the calculation of the cross section t statistic.

\[
t_{CS,AR_t} = \frac{\frac{1}{M} \sum_{k=1}^{M} AR_{kt}}{\sqrt{\frac{1}{M(M-1)} \sum_{k=1}^{M} (AR_{kt} - \frac{1}{M} \sum_{k=1}^{M} AR_{kt})^2}} \tag{8}
\]

\[
t_{CS,CAR} = \frac{\frac{1}{M} \sum_{k=1}^{M} CAR_k}{\sqrt{\frac{1}{M(M-1)} \sum_{k=1}^{M} (CAR_k - \frac{1}{M} \sum_{k=1}^{M} CAR_k)^2}} \tag{9}
\]

\[
t_{CS,BHAR} = \frac{\frac{1}{M} \sum_{k=1}^{M} BHAR_k}{\sqrt{\frac{1}{M(M-1)} \sum_{k=1}^{M} (BHAR_k - \frac{1}{M} \sum_{k=1}^{M} BHAR_k)^2}} \tag{10}
\]

The notation of \( M, S_k, k, \) and \( p \) is the same as explained in the formula of Patell’s Z.

Table 2 provides the result of the event analysis for \( T=1, 3, \) and 5. Panel A presents the results based on the recommendation rating. It is clear that analysts’ recommendations are associated with significant abnormal return around the announcement. Both “Strong Buy” and “Buy” recommendations are associated with an average positive abnormal return, while “Strong Sell” and “Sell” result in a negative average abnormal return. The magnitudes of the abnormal returns are consistent with their favorable/unfavorable level. “Strong Buy” rating is associated with about 2% daily abnormal return, and “Buy” rating reduces to around 0.7%. “Strong Sell” rating is accompanied by a negative 4% abnormal return, while “Sell” rating has a negative 3% abnormal return. All these average abnormal returns are significant at 95% confidence level.
regardless of the length of the event window. It is also interesting to note the significant negative abnormal return for the “Hold” recommendation, as a “Hold” rating is typically perceived to be a neutral signal. Chan et al. (2014) find that when analysts are facing uncertainty related to the future performance for a stock, they tend to issue ambiguous “Hold” instead of an explicit “Sell”. This paper confirms this finding as the market reaction to the “Hold” recommendation is equivalent to that to the “Strong Sell/Sell” recommendations.

Panel B presents the result based on the recommendation revision. For the recommendation initiations, the category of “Strong Buy/Buy” achieves a positive abnormal return around 1.1%, and the category of the “Strong Sell/Sell” recommendations is associated with a negative abnormal return around 3%. Still, the initiation of “Hold” has a negative expected abnormal return, which amounts to -1.6%. For the reiteration category, the abnormal returns are found to be insignificantly different from zero. According to the studies by Brown et al. (2009), the reiterations of the same ratings do not provide useful information about the stock performance, thus the market has a weak response to those reiterations. The results in this paper confirm the same findings regarding this effect. For the revision with a change of rating level, “Upgrade” is associated with a significant positive abnormal return, which amounts to about 3.0% for a [-1, +1] window and up to 3.2% for a [-1,+5] window. “Downgrade” exhibits the same effect as a “Sell” signal, which is associated with an abnormal return between -4.01% to --4.3%, depending on the choice of the event window.

The results from both Panel A and Panel B reveal several findings. Firstly, the market reactions to the “Buy” signal and the “Sell” signal is not symmetric. Based on the pure ratings, the “Strong Buy” rating is associated with weaker market reaction (2.16%) than that with a “Strong Sell” rating (-3.79%). Similarly, the market responses are more sensitive to the “Sell”
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rating than to the “Buy” rating. Based on the revision type, the market reaction asymmetry remains the same for the “Initiations”. For revision with change of rating levels, stocks response less to the “Upgrade” than to the “Downgrade”. Previous studies that focus on the issue of analysts’ over-optimism state that analysts are more likely to issue a favorable ratings than an unfavorable rating (B. M. Barber et al., 2006; Chan et al., 2014; Clarke et al., 2011; Malmendier & Shanthikumar, 2014). As the result of the over-optimism, analysts generate recommendations with different expected quality and the “Sell” signal contains more reliable information than the “Buy” signal. Therefore, the informative value from the recommendations with “Sell” signal is greater than that from the recommendations with “Buy” signal. Second important finding is the difference of the informative value that between the pure rating and the revision. Existing literature states that the revision of the recommendation rating contains more profitable information than the pure rating for the recommendation (B. M. Barber et al., 2010; Chan et al., 2014). This paper finds the evidence to support this claim in the recommendations’ informative value. The abnormal return for the “Upgrade” revision has a 2.95% CAR, while the “Strong Buy” rating only has 2.16% CAR. Similarly, the CAR for the “Downgrades” has the strongest abnormal return across all categories, which outperforms the “Strong Sell” rating.

4. Recommendation Investment Value

Despite the fact that the event analysis approach produces results that demonstrate the informative value of the analysts’ recommendations, the actual value that investors can achieve from the practical perspective cannot be simply deduced from the result of the event analysis. One major reason is that the actual profit of following recommendations is typically based on a much longer investment horizon, while the event analysis only focuses on a relatively short-term horizon. It is possible to make the specification of a longer window length in the event analysis,
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however the results for those long-horizon event study becomes much less reliable (M. Y. Chen, 2014). Another important reason is that it is more difficult for individual investor to utilize the “Sell” signal than to utilize the “Buy” signal. From the practical perspective, the trading strategy that requires the short-selling activity typically contains more restrictions than the long-only strategy, thus limits the profitability of the “Sell” signal. From the results in the event analysis, “Sell” signals generally outperform the “Buy” signals in the associated market reactions, therefore the disadvantage of utilizing these “Sell” signals further reduces the overall investment value of the recommendations.

To account for the long-term effectiveness of the analysts’ recommendations and the profitability from the actual trading activities, the portfolio construction approach is performed to evaluate the investment value. Similar to the event analysis approach, the portfolio construction approach includes two major aspects in the analysis. The first aspect considers the pure recommendation ratings, and the second aspect considers change of the recommendation rating.

**Portfolio Design**

All of the portfolios considered in this paper assume a long-only passive management strategy, and the trading signals are determined by the specified trading-rules on the observation of each individual recommendation. A value-weight and daily rebalancing schedule is applied to manage the portfolios. The weight of each stock in the portfolio is in proportion to the weight of the market capital value of that stock in the total market value of all the stocks in the portfolio. The value-weight has the advantageous over the equal-weight, as it reduces the overstate of the portfolio return and offers better representation of the economic significance of the results (B. Barber et al., 2001). In this paper, the daily portfolio return on day \( t \) is computed as follow:

\[
\text{Daily Portfolio Return at day } t = \sum_{i} w_i \Delta R_i
\]
\[ R_t = \sum_{i=1}^{N} w_{i,t} R_{i,t} \]  

(11)

where \( w_{i,t} \) is the weight of the stock \( i \) in the portfolio at day \( t \), \( R_{i,t} \) is the daily return for stock \( i \) at day \( t \), and the summation is overall all the \( N \) stocks in the portfolio at day \( t \). \( w_{i,t} \) is determined by the following equation:

\[ w_{i,t} = \frac{MV_{i,t-1}}{\sum_{I \in Portfolio} MV_{i,t-1}} = \frac{P_{i,t-1} S_{i,t-1}}{\sum_{I \in Portfolio} P_{i,t-1} S_{i,t-1}} \]  

(12)

where \( MV_{i,t-1} \) is the market capital value of stock \( i \) at day \( t-1 \), and \( (I \in Portfolio) \) indicates the set of stocks contained in the portfolio at day \( t-1 \). The market capital value is calculated as the product of stock price \( P_{i,t-1} \) for stock \( i \) at day \( t-1 \) and \( S_{i,t-1} \) the number of shares outstanding for the same stock at day \( t-1 \).

The transaction cost is also considered in the portfolio construction approach. This paper uses the bid-ask spread of the close stock price as the proxy to approximate the percentage loss due to the trading costs. The following formulas are used to calculate the portfolio return after the deduction of the transaction fees:

\[ R_{t,net} = \sum_{i=1}^{N} w_{i,t} R_{i,t,adjusted} \]  

(13)

\[ R_{i,t,adjusted} = \left( 1 - \frac{bid_{i,t} - ask_{i,t}}{P_{i,t}} \times \left( \frac{turnover_{i,t}}{drifted weight_{i,t}} \right) \right) \left( 1 + R_{i,t} \right) - 1 \]  

(14)

\[ drifted weight_{i,t}^{value} = \frac{w_{i,t}^{value} \times (1 + r_{t-1})}{\sum_{I \in Portfolio} w_{i,t}^{value} \times (1 + r_{t-1})} \]  

(15)

\[ turnover_{i,t} = |drifted weight_{i,t} - w_{i,t}| \]  

(16)

\[ turnover_{t} = \sum_{I \in Portfolio} turnover_{i,t} \]  

(17)

where \( R_{t,net} \) denotes the net portfolio return on day \( t \) after the transaction costs. \( R_{i,t,adjusted} \) is the adjusted return for stock \( i \) on day \( t \) with the consideration of the transaction cost. \( \frac{bid_{i,t} - ask_{i,t}}{P_{i,t}} \) is the bid-ask spread of stock \( i \) on day \( t \). Equation (16) calculates the two-way
turnover, in which the item $drifted \, w_{i,t}$ is the drifted weight for the stock $i$ at day $t$ due to the appreciation of the stock value of stock $i$ on day $t-1$. The portfolio turnover on day $t$ is given by the summation of each individual stock turnover in the portfolio, as specified in equation (17).

The general guideline for the portfolio construction is that stocks with “BUY” signal will be added into the portfolio when the signal is observed. If “SELL” signals are observed for stocks in the portfolio, then the stocks will be sold out, otherwise no actions are taken.

**Unconditional Investment Decision (Portfolio A)**

The analysis begins with an unconditional investment decision (Portfolio A), which assumes that investors take the “BUY/SELL” signal without the aid of any other information. For Portfolio A, the “BUY/SELL” signal for a rating-based strategy is obtained from the information on the pure rating of the recommendations, while the “BUY/SELL” signal for a revision-based strategy is derived from the change of the rating for the recommendation. For the rating-based portfolio, a stock will be added into the portfolio when a “Strong Buy” or “Buy” recommendation is issued, and a stock that is in the portfolio will be excluded when it receives a “Strong Sell” or “Sell” recommendation. Despite the fact that the “Hold” rating is associated with a negative average abnormal return in the event analysis, this paper ignores the “Hold” and will not adjust the portfolio weights if a “Hold” is observed as the “Hold” rating literally provides neutral implication regarding the trading direction. This paper only considers the long-only portfolio management strategy, therefore if the investor observes a “Sell” rating for a stock that is not in the portfolio, they cannot take any action on this recommendation. For a revision-based portfolio, the trading decision rule is based on the change of recommendation ratings. The portfolio adds stocks with an “Upgrade” and excludes stocks with a “Downgrade”.

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In the case of an initiation, the initiation of the “Strong Buy” and “Buy” is treated as an “Upgrade” from uninformed neutral rating to a favorable rating and the initiation of “Sell” and “Strong Sell” is treated as equivalent to a “Downgrade” from neutral to an unfavorable rating. The new initiation of the “Hold” rating is excluded from the investment decision because of the same reason stated in the rating-based trading rules. All the reiterations of the recommendations are also not consider as previous studies show that the stocks do not exhibit strong market reaction to the reiteration of the same rating. When multiple recommendations are observed for the same stock on a specific trading date, the investment decision is formed by the following criteria. For the rating-based portfolio, the average rating on that date is calculated and an average rating above 3 is a “BUY” signal, average rating equal 3 is an equivalent “Hold”, otherwise a “SELL” signal. For the revision-based portfolio, the proportion of the individual “Upgrade” and “Downgrade” is calculation, if the proportion of the “Upgrade” is greater, those recommendations provide an equivalent “BUY” signal, equal proportion leads to an omission of those recommendations, and smaller proportion of the “Upgrade” compared to “Downgrade” results in a “Sell” signal. Similar to the research design proposed by B. Barber et al. (2001), this paper also considers the cost of investment delays. It is reasonable to assume that individual investors may need some time to react to the analysts’ recommendations or they might have some disadvantage in receiving the recommendation information when compared to the institutional investors. This paper considers the specifications on alternative portfolios that have 1-day, and 5-day delays in responding to the recommendations through the portfolio management activity. In addition to the delayed actions, this paper also considers the impact of different holding horizons for the stocks to be remained in the portfolio. To implement the strategy with the specified holding horizon, for any stock in the portfolio, the decision to sell that
stock will be made either when the investor observes the “Sell” signal, or when the time that the stock remains in the portfolio hits the specified holding period. For example, if the investor specifies that the stocks should only be kept in the portfolio for 30 trading days, then that stock will be excluded from the portfolio after 30 days unless there is another “Buy” signal observed within 30 days holding period. This paper considers the specified holding horizon of 30-day, 60-day, 120-day, 360-day, 720-day, and infinity holding period. A shorter specified holding horizon focuses on capturing the short-term profitability of the recommendations, and a longer specified holding horizon aims to capture more of the investment value from a long-term perspective. Moreover, setting the specified holding period too short leads to a higher daily turnover and incurs greater transaction cost, therefore this paper also offers intuitive implications on how to balance gain of the long-term investment value and the loss of the frequent transaction cost.

**Portfolio Performance**

Figure 1 provides the visualization of the growth of the value of the portfolios that follow the trading signal of the recommendation. Figure 1(a) illustrates the capital growth of the rating-based portfolio. Assuming an equal $1 initial investment value, while the benchmark of the market portfolio only increases to $3.1 through the investment period, the rating-based portfolio achieves a $4.7 ending investment value without the consideration of the transaction cost, and $4.2 after deducting the transaction cost. Figure 1(b) presents the growth chart for the revision-based portfolio, the ending value of the portfolio is as high as $13.5 without the consideration of the transaction cost and $9.3 after subtracting the transaction cost. The outperformance over the market portfolio for both the rating-based strategy and the revision-based strategy provides direct evidence that shows the investment value. The superior performance of the revision-based
portfolio also confirms that the information contained in the change of the recommendation rating brings more profitability than the information of only the pure rating.

Table 3 presents the comparison of the portfolio performance across different specifications on delayed actions and holding horizon. Panel A shows the portfolio abnormal return (alpha) from the Carhart Model for the rating-based strategy, and Panel B shows the alpha for the revision-based strategy. The results provide several important findings regarding the properties of the investment value of the analysts’ recommendations. Firstly, the profitability of the recommendations diminishes quickly if the trading action is delayed. Both the rating-based strategy and the revision-based strategy earn positive alpha after the deduction of the transaction cost without the delay, regardless of the length for the specified holding horizon. However, if the trading action is delayed by 1 day, the alpha is still significant for the revision-based strategy before the transaction costs and becomes insignificant for both strategies net of the transaction costs. If the action is delayed by 5 days, the portfolio alpha totally vanishes before the transactions, and a net of loss incurs after deducting the transaction cost. Secondly, the investment value of the recommendations decreases with the increase of the specified holding horizon. The alpha for both investment strategies monotonically decreases when the specified holding horizon increases from 30 trading days to infinity horizon. This finding does not support the hypothesis that there will be an optimal holding horizon that achieves a maximized after cost return, or at least this optimal holding horizon is less than 30 days. Some researchers (Jegadeesh & Kim, 2006, 2010; Womack, 1996) find that the market price of the recommended stock continue to reflect the information in recommendation revisions up to several months into the future. However, the finding in this paper makes it clear that due to the information decay along the investment horizon (Fishwick, 2007), it is impossible to make profit from these long-term
market reactions from a practical perspective. To summarize the findings in other words, the investment value of the recommendations is by nature temporal and the profitability elapses quickly if the investor has any delay in responding to the signals. Lastly, given the same specified holding period and delayed action, the revision-based strategy consistently outperforms the rating-based strategy. This finding is consistent with the result in previous study (B. M. Barber et al., 2007), which implies that the information of recommendation revision can be translated into more investment value than the information of the pure recommendation rating.

**Conditional Investment Decision based on the Observed Market Reaction (Portfolio B)**

Since one of the major purpose in this paper is to explore the relationship between the recommendations’ informative value and the investment value, alternative portfolios are designed to evaluate the long-term profitability conditional on the short-term market reactions. The result of the analysis on Portfolio A reveals that delays in the investment actions significantly reduce the profitability of the recommendations. However, it might be interesting to ask whether investor can still obtain some helpful information during the period of delay that allows them to make better investment decision thus offsets the loss of the investment opportunity. Portfolio B is constructed to answer this question. In particular, the investment strategy incorporates the information of the short-term effectiveness observed during the period of delay into the decision of whether to follow the recommendation or not. Through the observation of the market reaction during the period of delay, investors have the knowledge about the short-term effectiveness of the individual recommendation and they can chose only a subset of the “qualified” recommendations to follow. Like the strategy for Portfolio A, Portfolio B also discerns between the rating-based strategy and the revision-based information. Trading
rules on whether to follow the recommendation or not are specified for sub-portfolios, so that the relationship between the short-term market reaction and the long-term profitability can be assessed. The first set of the sub-portfolios consider only whether the individual recommendation is “effective” or not, and the second set of sub-portfolios consider the level of the “effectiveness”. The individual recommendation is defined to be “effective” if the observed subsequent short-term buy-and-hold abnormal return has the same sign with the expected abnormal return for the same type of recommendation; otherwise the individual recommendation is defined as “ineffective”. For example a particular “Strong Buy” to “Buy” recommendation with a negative buy-and-hold abnormal return will the treated as “ineffective” for the rating-based strategy (“Buy” rating is associated with positive abnormal return) and “effective” for the revision-based strategy (“Downgrade” is associated with negative abnormal return).

To evaluate the first set of sub-portfolios, comparison of the portfolio performance between the strategy that follows only “effective” recommendations against strategy that follow only “ineffective” recommendation is performed. For the second set of the sub-portfolios, the decision to follow the recommendations will be based on the level of the observed “effectiveness” and the comparison of the portfolio performance is made among different level of “effectiveness”. To account for the different level of “effectiveness”, this analysis divides the sub-portfolio by the quintile of the abnormal returns from the event analysis. To construct each portfolio, we first sort the individual effectiveness (the buy-and-hold abnormal return, for abnormal return with negative average for the same type, the sign is reversed) according to the recommendation type in the previous calendar quarter and then find the quintile value for the effectiveness. If the observed buy-and-hold abnormal return is within the i\textsuperscript{th} quintile from previous quarter, then it will be treated as a “qualified” signal for portfolio B_Qi. As the result,
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portfolio B_Q1 represents the subset of recommendations with least observed effectiveness, and portfolio B_Q5 represents the collection of recommendations with highest observed effectiveness.

Table 4 presents the annualized alpha for the sub-portfolios as constructed by the corresponding trading rules. Panel A and Panel B presents the portfolio evaluation that assumes a 1-day delay, and Panel C and Panel D extends the period of delay into 5 days. The evaluation of the portfolio performance provides very surprising results. The first thing to notice is that regardless of whether the trading signal is rating-based or revision-based, and regardless of the length of the specified holding horizon, none of these sub-portfolios achieves a significant positive abnormal return. The second thing that calls our attentions is that there is almost no obvious pattern regarding the relationship between the level of the short-term effectiveness and the long-term profitability. These two findings, again, suggest that analysts’ recommendations only have temporal effect over the stock prices and a large part of the investment profitability can only be attributed to the instantaneous stock price fluctuation, thus making it hard to exploit the long-term profitability if the investor has any delay in following the recommendations from a practical perspective.

Conditional Investment Decision based on Analysts’ Previous Performance (Portfolio C)

The analysis of the unconditional investment decision (Portfolio A) and the conditional investment decision based on the observed market reaction at individual recommendation level (Portfolio B) shows one very important finding regarding the effective information horizon for the analysts’ recommendation, which the informative content of the recommendation decays quickly. If the trading actions are delayed, the gain of the confirmation of whether the
recommendation is short-term effective or not is never enough to make remedy for the loss of investment opportunity. From the practical perspective, investors should avoid any delay in following the recommendations and timely to capture the major portion of the investment value of the recommendations. However, it is still possible to allow investors to make the decision on whether to follow the recommendation or not based on their trustiness of the recommendation or the reliability analysts who write the recommendation.

In the following part, we focus on the incremental investment value that can be attributed to the filtering of reliable analysts. The analysis assumes no delayed actions, however the decision to follow the recommendation is contingent on the historical performance of the analyst who writes the recommendation. Researchers (Brown et al., 2009; Casey, 2013; Stickel, 1995) find that analysts’ reputation influences their recommendation effectiveness. Reputable analysts are typically associated with superior accuracy in earning forecast and less over-optimism in recommendation (Malmendier & Shanthikumar, 2014). The analysis of the conditional investment decision based on the filtering of analysts considers the influence of the analysts’ reputation. Instead of using the conventional choice of the all-star status to proxy the analysts’ reputation for reliability, this paper uses the consistency of the short-term effectiveness in the previous issued recommendations as the filtering criteria. There are three major reasons for this choice. First of all, the short-term effectiveness is easy to calculate, thus offering convenience over other measurements from a practical perspective. Secondly, matching the IBES database to the all-star status results in a large attrition of the recommendation records, which adversely affects the accuracy in the portfolio construction approach. Lastly, Hilary and Hsu (2013) find that analysts’ capability in affecting the stock price movement is consistent, therefore previous
recommendation performance by the same analysts provides better estimation of the reliability for the current recommendation.

This paper adopts two measurements to denote the analysts’ previous recommendation performance. The first measurement is the proportion of the effective recommendations to the total recommendations that an analyst has issued before the current recommendation. The second measurement is the average effectiveness for the recommendations that an analyst has issued before the current recommendation. It is assumed that when observing a recommendation, the investor check the previous performance of the analyst first, and then decide whether to follow the recommendation or not. As the result of such a filtering, the analysts’ first recommendations are excluded from the analysis as there is no summary of the analysts’ historical performance for these recommendations. The investment strategy that employs the analysts’ previous recommendation performance (Portfolio C) is constructed in the following manner. Portfolio C1 uses the proportion of the effective recommendation as the primary measurement, the average effectiveness as secondary measurement, to account for the analysts’ historical performance. The sub-portfolio of C1-Qi follows the recommendations within different quintile of the primary measurement. In the case of conflicting opinions for different analysts with equal historical performance in the primary measurement, the analysts with highest secondary measurement will be followed. If the secondary measurement is still equal, the analyst who has the longest working experience will be followed, otherwise these conflicting opinions will be discarded. Portfolio C2 and C2-Qi follow the same logic, and switch the primary measurement and the second measurement. Since the purpose of designing Portfolio C is to extract the investment value of the recommendation from the existing information as much as possible, the analysis only focuses on the revision-based strategy.
Table 5 shows the result of the abnormal returns for Portfolio C and its corresponding sub-portfolios. Panel A provides results of Portfolio C1 and Panel B shows the results of Portfolio C2. The incremental investment value by filtering analysts without trackable performance record is identified by the comparison between the second column of Table 5 and the second column of Panel B in Table 3. Both the alpha before the transaction cost and the alpha after deducting the transaction cost have been significantly improved, which suggests that the information regarding the previous recommendation effectiveness at the individual analyst level can be translated into the investment profitability. Therefore, eliminating recommendations with uncertain reliability enhances the performance of the portfolio. In the examination of C1_Q\textsubscript{i} and C2_Q\textsubscript{i}, there is obvious positive relation between the realized portfolio alpha and the analysts’ historical performance. This finding has a very importation implication for the practitioners, which informs that analysts do exhibit consistent capability and the previous recommendation effectiveness serves as good indicator for the future recommendation effectiveness. Therefore, investing in analysts with superior historical performance is beneficial to investors, which allows them achieve better return in the future as well. Another noticeable finding is that Portfolio C1_Q\textsubscript{i} achieves better performance in the lower quintile than Portfolio C2_Q\textsubscript{i}, while Portfolio C2_Q\textsubscript{i} outperforms Portfolio C1_Q\textsubscript{i} in the upper quintile. This finding is also informative to practitioners. Portfolio C1 accounts for the percentage of the correct predictions, which is less powerful in identifying the consistency of the performance than the actual average effectiveness when the analysts have only a few outstanding records. However, when an analyst accumulates enough trackable records during his professional career, the proportion of the correct recommendations becomes a better proxy for the historical performance as it reduces the bias towards a particular extreme success or failure. Therefore, the advantage and disadvantage over
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The choice of historical performance measurement is reflected by the difference of the investment performance between Portfolio C1 and Portfolio C2 within each quintiles. Lastly, comparing Portfolio C with its corresponding sub-portfolios. We find that each sub-portfolio underperforms the aggregated portfolio, and each sub-portfolio earns insignificant alpha after subtracting the transaction cost even if the alpha before the transaction cost is significant and great. This finding can be explained through several aspects. First, sub-portfolio contains less recommendations, which means less information and less investment opportunity, therefore it reduces the potential profitability and earns less than the aggregated portfolio. Secondly, narrowing to a small subset of the information results in abrupt portfolio rebalancing, higher turnover, and higher transaction, therefore the alpha after the transaction cost diminishes for the sub-portfolios. From the practitioner’s perspective, this finding suggest the investors focus on a wide scope of the investment opportunity to extract the value of the analysts’ recommendations as much as possible. From the academic’s perspective, this finding brings caution to the research that employs the portfolio construction approach to analyze the value of trading signal, since result and conclusion from this method is very sensitive to the choice of the data. Conflicting results regarding the investment value of the analysts’ recommendations (B. M. Barber et al., 2007; Casey, 2013; Jegadeesh & Kim, 2006) can be partially explained by this reason. In order to keep the research result unbiased, researchers need to keep the original trading signals as many as possible.

5. Conclusion and Discussion

This paper seeks to unveil the investment value of the analysts’ recommendation from the practical perspective and explore the relationship between the short-term recommendation
WHICH ANALYSTS’ RECOMMENDATIONS SHOULD WE TRUST? - DEVELOPING AN EFFECTIVE STRATEGY IN THE PORTFOLIO MANAGEMENT PRACTICE

effectiveness and long-term portfolio profitability. While previous studies employ the portfolio construction approach only to illustrate the existence of the profitability, this paper examines the extent to which the value can be exploited from the available information regarding the analyst’s recommendations. This paper documents several important findings. First, the portfolio that follows analysts’ recommendations earns positive abnormal return, and using recommendation revisions achieves better performance than using pure recommendation ratings. Second, the effectiveness of the recommendation is by nature temporal, therefore the portfolio profitability decreases significantly if the trading action is delayed, or the stocks stay in the portfolio for too long. Thirdly, the short-term recommendation effectiveness does not predict the long-term stock performance at the individual recommendation level from a practical perspective, therefore the informative gain of short-term effectiveness is not enough to compensate for the loss of delayed actions. Lastly, screening recommendations with uncertainty at the analyst’s level improves the portfolio performance, however narrowing the scope of the information limits the portfolio profitability. These findings contribute to the academia by qualitatively breakdown the add-value of analysts’ recommendations into the investment value and informative value. The major difference between the two types of value is the length of the investment horizon. This paper finds that the added value of the analysts’ recommendation is largely concentrated on the short-term investment horizon. The information regarding the short-term performance aggregated at the individual analyst level can improve the extraction of the incremental long-term investment value. Analysts’ performance consistency intermediates the long-term investment value and the short-term informative value. This paper should also be appealing to practitioners. In this paper, different rule-based passive portfolio management strategies are compared, which can be easily replicated from the practical perspective. This paper also proposes two simple measurement for
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The major limitation of this paper resides in the constraint of the portfolio design. This paper adopts the long-only strategy to manage the portfolio, therefore limiting the investment opportunity of short-selling on the unfavorable recommendations. Unfavorable recommendations are found to be more effective than the favorable recommendations. Therefore, the long-only strategy cannot fully unlock the investment value compared to a long-short strategy.

Incorporating the short-selling and determining the weight of each asset in the portfolio requires the shift from the passive portfolio management strategy to an active portfolio management strategy. Such an active portfolio construction approach is more applicable under the Black-Litterman framework, which combines both the expert opinions and the market data in a Bayesian manner (Black & Litterman, 1992; Idzorek, 2002; Meucci, 2010). The application of this approach is beyond the scope of this paper, and is left for future research.

Reference


WHICH ANALYSTS’ RECOMMENDATIONS SHOULD WE TRUST? - DEVELOPING AN EFFECTIVE STRATEGY IN THE PORTFOLIO MANAGEMENT PRACTICE


Casey, R. J. (2013). Do independent research analysts issue more or less informative recommendation revisions? *Advances in Accounting, 29*(1), 36-49.


### Table 1. Frequency Distribution of Recommendations

<table>
<thead>
<tr>
<th>Previous Rating</th>
<th>Current Rating</th>
<th>Overall</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Strong Buy</td>
<td>Buy</td>
</tr>
<tr>
<td>None</td>
<td>44,249</td>
<td>57,913</td>
</tr>
<tr>
<td></td>
<td>(11.6%)</td>
<td>(15.2%)</td>
</tr>
<tr>
<td>Strong Buy</td>
<td>6,036</td>
<td>12,015</td>
</tr>
<tr>
<td></td>
<td>(1.6%)</td>
<td>(3.2%)</td>
</tr>
<tr>
<td>Buy</td>
<td>12,252</td>
<td>12,636</td>
</tr>
<tr>
<td></td>
<td>(3.2%)</td>
<td>(3.3%)</td>
</tr>
<tr>
<td>Hold</td>
<td>17,793</td>
<td>25,137</td>
</tr>
<tr>
<td></td>
<td>(4.7%)</td>
<td>(6.6%)</td>
</tr>
<tr>
<td>Sell</td>
<td>322</td>
<td>1,146</td>
</tr>
<tr>
<td></td>
<td>(.1%)</td>
<td>(.3%)</td>
</tr>
<tr>
<td>Strong Sell</td>
<td>402</td>
<td>161</td>
</tr>
<tr>
<td></td>
<td>(.1%)</td>
<td>(.%)</td>
</tr>
<tr>
<td>Overall</td>
<td>81,054</td>
<td>109,008</td>
</tr>
<tr>
<td></td>
<td>(21.3%)</td>
<td>(28.7%)</td>
</tr>
</tbody>
</table>

*Note: The numbers in the parentheses represent the relative proportion of each sub-category of the recommendations to the total number of records in the data.*
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Table 2. Abnormal Return from the Event Analysis

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CAR</td>
<td>BHAR</td>
<td>CAR</td>
</tr>
<tr>
<td>Strong Buy</td>
<td>2.16% **</td>
<td>2.03% ***</td>
<td>2.16% **</td>
</tr>
<tr>
<td>(94.02)</td>
<td>(68.81)</td>
<td></td>
<td>(94.02)</td>
</tr>
<tr>
<td>Buy</td>
<td>.75% **</td>
<td>.75% ***</td>
<td>.77% **</td>
</tr>
<tr>
<td>(66.16)</td>
<td>(28.72)</td>
<td></td>
<td>(51.26)</td>
</tr>
<tr>
<td>Hold</td>
<td>-1.85% ***</td>
<td>-1.84% ***</td>
<td>-1.95% ***</td>
</tr>
<tr>
<td>(-153.06)</td>
<td>(-73.44)</td>
<td></td>
<td>(-118.59)</td>
</tr>
<tr>
<td>Sell</td>
<td>-3.05% ***</td>
<td>-3.01% ***</td>
<td>-3.18% ***</td>
</tr>
<tr>
<td>(-100.78)</td>
<td>(-37.6)</td>
<td></td>
<td>(-77.98)</td>
</tr>
<tr>
<td>Strong Sell</td>
<td>-3.79% ***</td>
<td>-3.81% ***</td>
<td>-4.02% ***</td>
</tr>
<tr>
<td>(-75.18)</td>
<td>(-28.9)</td>
<td></td>
<td>(-58.09)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Panel B: Revision</th>
<th>CAR</th>
<th>BHAR</th>
<th>CAR</th>
<th>BHAR</th>
<th>CAR</th>
<th>BHAR</th>
</tr>
</thead>
<tbody>
<tr>
<td>Initiation</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hold</td>
<td>-1.59% ***</td>
<td>-1.58% ***</td>
<td>-1.7% ***</td>
<td>-1.71% ***</td>
<td>-1.75% ***</td>
<td>-1.79% ***</td>
</tr>
<tr>
<td>(-98.85)</td>
<td>(-51.21)</td>
<td></td>
<td>(-76.56)</td>
<td>(-49.9)</td>
<td>(-64.7)</td>
<td>(-47.58)</td>
</tr>
<tr>
<td>Strong Buy</td>
<td>1.09% ***</td>
<td>1.09% ***</td>
<td>1.12% ***</td>
<td>1.09% ***</td>
<td>1.11% ***</td>
<td>1.03% ***</td>
</tr>
<tr>
<td>(80.41)</td>
<td>(44.56)</td>
<td></td>
<td>(62.29)</td>
<td>(37.82)</td>
<td>(52.64)</td>
<td>(31.1)</td>
</tr>
<tr>
<td>Strong Sell</td>
<td>-2.81% ***</td>
<td>-2.75% ***</td>
<td>-3.02% ***</td>
<td>-3% ***</td>
<td>-3.13% ***</td>
<td>-3.15% ***</td>
</tr>
<tr>
<td>(-72.51)</td>
<td>(-24.76)</td>
<td></td>
<td>(-56.11)</td>
<td>(-29.82)</td>
<td>(-47.43)</td>
<td>(-31.71)</td>
</tr>
<tr>
<td>Reiteration</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hold</td>
<td>-.07% *</td>
<td>-.07%</td>
<td>-.03%</td>
<td>-.05%</td>
<td>.05%</td>
<td>.02%</td>
</tr>
<tr>
<td>(-2.22)</td>
<td>(-1.21)</td>
<td></td>
<td>(-1.73)</td>
<td>(-.76)</td>
<td>(-1.46)</td>
<td>(-.26)</td>
</tr>
<tr>
<td>Strong Buy</td>
<td>.01%</td>
<td>.%</td>
<td>-.03%</td>
<td>-.08%</td>
<td>-.1%</td>
<td>-.19% **</td>
</tr>
<tr>
<td>(-1.31)</td>
<td>(-.08)</td>
<td></td>
<td>(-1.02)</td>
<td>(-1.21)</td>
<td>(-.86)</td>
<td>(-2.4)</td>
</tr>
<tr>
<td>Strong Sell</td>
<td>-.22% ***</td>
<td>-.22%</td>
<td>-.16% **</td>
<td>-.14%</td>
<td>-.12% *</td>
<td>-.16%</td>
</tr>
<tr>
<td>(-3.51)</td>
<td>(-1.58)</td>
<td></td>
<td>(-2.72)</td>
<td>(-.8)</td>
<td>(-2.29)</td>
<td>(-.87)</td>
</tr>
<tr>
<td>Upgrade</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2.95% **</td>
<td>3.14% ***</td>
<td>3.13% ***</td>
<td>3.23% ***</td>
<td>3.2% **</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(173.45)</td>
<td>(81.33)</td>
<td></td>
<td>(134.35)</td>
<td>(76.57)</td>
<td>(113.55)</td>
<td>(71.52)</td>
</tr>
<tr>
<td>Downgrade</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(-4.01% ***</td>
<td>-4.20% ***</td>
<td>-4.2% ***</td>
<td>-4.28% ***</td>
<td>-4.32% ***</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(-223.96)</td>
<td>(-94.89)</td>
<td></td>
<td>(-173.44)</td>
<td>(-93.81)</td>
<td>(-146.5)</td>
<td>(-90.56)</td>
</tr>
</tbody>
</table>

Note: The numbers in the parentheses represent the test statistic, the Patell’s Z is displayed for CAR and cross sectional T is displayed for BHAR.

*** Significant at 0.01 level; ** significant at 0.05 level; * significant at 0.10 level.
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Table 3. Performance Evaluation for Unconditional Investment Decision (Portfolio A)

<table>
<thead>
<tr>
<th>Specified Holding Horizon</th>
<th>Panel A: Rating-Based Strategy (Alpha no cost/Alpha after cost)</th>
<th>Panel B: Revision-Based Strategy (Alpha no cost/Alpha after cost)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>No Delayed Action</td>
<td>Delayed by 1 Day</td>
</tr>
<tr>
<td></td>
<td>3.11% *** / 3.11% ***</td>
<td>2.42% ** / (1.80%)</td>
</tr>
<tr>
<td></td>
<td>2.34% *** / 2.34% ***</td>
<td>1.79% ** / (0.71%)</td>
</tr>
<tr>
<td></td>
<td>1.94% *** / 1.94% ***</td>
<td>1.37% / (0.26%)</td>
</tr>
<tr>
<td></td>
<td>1.31% *** / 1.31% ***</td>
<td>0.68% / (0.29%)</td>
</tr>
<tr>
<td></td>
<td>1.35% *</td>
<td>0.70% / (0.11%)</td>
</tr>
<tr>
<td></td>
<td>1.49% **</td>
<td>0.78% / 0.05%</td>
</tr>
<tr>
<td></td>
<td>9.03% *** / 9.03% ***</td>
<td>2.26% ** / (2.49%)***</td>
</tr>
<tr>
<td></td>
<td>7.15% *** / 7.15% ***</td>
<td>1.96% *** / (1.21%)</td>
</tr>
<tr>
<td></td>
<td>6.57% *** / 6.57% ***</td>
<td>1.82% *** / (0.60%)</td>
</tr>
<tr>
<td></td>
<td>5.98% *** / 5.98% ***</td>
<td>1.71% *** / (0.34%)</td>
</tr>
<tr>
<td></td>
<td>5.93% *** / 5.93% ***</td>
<td>1.76% *** / (0.26%)</td>
</tr>
<tr>
<td></td>
<td>5.88% *** / 5.88% ***</td>
<td>1.78% *** / (0.25%)</td>
</tr>
</tbody>
</table>

**Note:** Both Panel A and Panel B report the annual abnormal return (Alpha) for the specified portfolio. The annual alpha is calculated by the multiplication of 252 (the number of trading days per year) and the daily abnormal return from the Carhart Model. Numbers in the parentheses indicate negative value.

*** Significant at 0.01 level; ** significant at 0.05 level; * significant at 0.10 level.
Table 4. Performance Evaluation for Conditional Investment Decision based on The Observed Recommendation Effectiveness

(Portfolio B)

**Panel A: Rating-Based Strategy (Alpha no cost/Alpha after cost); Period of Delay 1 Day**

<table>
<thead>
<tr>
<th>Specified Holding Horizon</th>
<th>(Effective)</th>
<th>(Ineffective)</th>
<th>(B_Q1)</th>
<th>(B_Q2)</th>
<th>(B_Q3)</th>
<th>(B_Q4)</th>
<th>(B_Q5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>(0.81%)/(5.27%)***</td>
<td>(0.07%)/(14.70%)***</td>
<td>0.07%/(4.67%)</td>
<td>0.49%(0.97%)</td>
<td>0.30%/(1.19%)</td>
<td>0.52%(3.73%)**</td>
<td>(0.30%)/(57.38%)***</td>
</tr>
<tr>
<td>60</td>
<td>(0.01%)/(2.84%)***</td>
<td>0.60%(2.29%)**</td>
<td>(0.25%)/(2.72%)</td>
<td>0.14%(1.22%)</td>
<td>0.33%(1.04%)</td>
<td>0.89%(1.51%)</td>
<td>0.38%(47.41%)***</td>
</tr>
<tr>
<td>120</td>
<td>0.18%(1.90%)</td>
<td>0.44%(1.54%)</td>
<td>0.55%(0.94%)</td>
<td>0.24%(0.83%)</td>
<td>0.28%(0.88%)</td>
<td>(0.07%)/(1.46%)</td>
<td>0.33%(35.23%)***</td>
</tr>
<tr>
<td>360</td>
<td>0.09%(1.57%)</td>
<td>0.28%(1.21%)</td>
<td>0.23%(0.53%)</td>
<td>0.15%(0.60%)</td>
<td>0.02%(0.83%)</td>
<td>0.12%(0.63%)</td>
<td>0.54%(19.62%)***</td>
</tr>
<tr>
<td>720</td>
<td>0.10%(1.52%)</td>
<td>0.27%(1.15%)</td>
<td>0.34%(0.23%)</td>
<td>0.06%(0.58%)</td>
<td>0.25%(0.44%)</td>
<td>0.37%(0.21%)</td>
<td>0.37%(14.10%)***</td>
</tr>
<tr>
<td>infinity</td>
<td>0.13%(1.49%)</td>
<td>0.30%(1.11%)</td>
<td>0.26%(0.22%)</td>
<td>0.21%(0.35%)</td>
<td>0.23%(0.37%)</td>
<td>0.38%(0.10%)</td>
<td>0.53%(9.95%)***</td>
</tr>
</tbody>
</table>

**Panel B: Revision-Based Strategy (Alpha no cost/Alpha after cost); Period of Delay 1 Day**

<table>
<thead>
<tr>
<th>Specified Holding Horizon</th>
<th>(Effective)</th>
<th>(Ineffective)</th>
<th>(B_Q1)</th>
<th>(B_Q2)</th>
<th>(B_Q3)</th>
<th>(B_Q4)</th>
<th>(B_Q5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>0.32%(13.89%)*</td>
<td>1.67%(3.32%)</td>
<td>1.03%(4.07%)</td>
<td>1.82%(49.63%)***</td>
<td>0.56%(51.47%)***</td>
<td>1.60%(53.15%)***</td>
<td>(1.86%)/(6.67%)***</td>
</tr>
<tr>
<td>60</td>
<td>0.41%(12.21%)***</td>
<td>1.34%(1.75%)</td>
<td>0.75%(2.13%)</td>
<td>0.25%(46.36%)***</td>
<td>1.03%(47.66%)***</td>
<td>(0.13%)/(49.24%)***</td>
<td>(1.18%)/(4.04%)*</td>
</tr>
<tr>
<td>120</td>
<td>0.65%(11.91%)*</td>
<td>0.99%(1.27%)</td>
<td>0.58%(1.38%)</td>
<td>0.42%(42.80%)***</td>
<td>0.69%(43.22%)***</td>
<td>(0.52%)/(44.54%)***</td>
<td>(0.70%)/(2.49%)*</td>
</tr>
<tr>
<td>360</td>
<td>0.65%(11.70%)*</td>
<td>0.87%(0.96%)</td>
<td>0.54%(0.69%)</td>
<td>0.04%(35.76%)***</td>
<td>0.74%(35.77%)***</td>
<td>(0.45%)/(37.36%)***</td>
<td>(0.21%)/(1.50%)*</td>
</tr>
<tr>
<td>720</td>
<td>0.66%(11.74%)*</td>
<td>0.85%(0.93%)</td>
<td>0.70%(0.42%)</td>
<td>0.10%(32.87%)***</td>
<td>0.76%(33.03%)***</td>
<td>(0.35%)/(34.86%)***</td>
<td>(0.08%)/(1.30%)*</td>
</tr>
<tr>
<td>infinity</td>
<td>0.66%(11.82%)*</td>
<td>0.84%(0.94%)</td>
<td>0.69%(0.40%)</td>
<td>0.13%(32.22%)***</td>
<td>0.67%(32.48%)***</td>
<td>(0.34%)/(33.96%)***</td>
<td>(0.03%)/(1.23%)*</td>
</tr>
</tbody>
</table>
### Panel C: Rating-Based Strategy (Alpha no cost/Alpha after cost); Period of Delay 5 Days

<table>
<thead>
<tr>
<th>Specified Holding Horizon</th>
<th>(Effective)</th>
<th>(Ineffective)</th>
<th>(B_Q1)</th>
<th>(B_Q2)</th>
<th>(B_Q3)</th>
<th>(B_Q4)</th>
<th>(B_Q5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>(0.84%)/(5.31%)***</td>
<td>1.63%/(2.95%)*</td>
<td>1.47%/(3.28%)</td>
<td>0.19%/(1.23%)</td>
<td>(0.05%)/(1.42%)</td>
<td>(0.73%)/(5.23%)***</td>
<td>(0.69%)/(57.91%)***</td>
</tr>
<tr>
<td>60</td>
<td>(0.92%)/(3.84%)***</td>
<td>1.67%/(1.11%)</td>
<td>1.35%/(1.21%)</td>
<td>(0.02%)/(1.40%)</td>
<td>0.18%/(1.11%)</td>
<td>0.27%/(2.23%)</td>
<td>(0.04%)/(48.06%)***</td>
</tr>
<tr>
<td>120</td>
<td>(0.51%)/(2.53%)***</td>
<td>1.18%/(0.76%)</td>
<td>1.75%/(0.25%)</td>
<td>0.15%/(1.00%)</td>
<td>0.44%/(0.66%)</td>
<td>0.51%/(0.91%)</td>
<td>0.18%/(37.07%)***</td>
</tr>
<tr>
<td>360</td>
<td>(0.70%)/(2.42%)***</td>
<td>1.59%/(0.07%)</td>
<td>0.80%/(0.04%)</td>
<td>0.19%/(0.63%)</td>
<td>0.26%/(0.56%)</td>
<td>0.35%/(0.47%)</td>
<td>0.47%/(20.63%)***</td>
</tr>
<tr>
<td>720</td>
<td>(0.61%)/(2.23%)***</td>
<td>1.48%/(0.03%)</td>
<td>0.59%/(0.11%)</td>
<td>0.25%/(0.49%)</td>
<td>0.29%/(0.43%)</td>
<td>0.43%/(0.22%)</td>
<td>0.09%/(15.70%)***</td>
</tr>
<tr>
<td>infinity</td>
<td>(0.62%)/(2.23%)***</td>
<td>1.50%/(0.06%)</td>
<td>0.83%/0.30%</td>
<td>0.40%/(0.23%)</td>
<td>0.30%/(0.31%)</td>
<td>0.64%/0.10%</td>
<td>0.44%/(10.89%)***</td>
</tr>
</tbody>
</table>

### Panel D: Revision-Based Strategy (Alpha no cost/Alpha after cost); Period of Delay 5 Days

<table>
<thead>
<tr>
<th>Specified Holding Horizon</th>
<th>(Effective)</th>
<th>(Ineffective)</th>
<th>(B_Q1)</th>
<th>(B_Q2)</th>
<th>(B_Q3)</th>
<th>(B_Q4)</th>
<th>(B_Q5)</th>
</tr>
</thead>
<tbody>
<tr>
<td>30</td>
<td>(0.63%)/(22.17%)***</td>
<td>1.70%/(2.99%)</td>
<td>0.81%/(4.48%)</td>
<td>1.53%/(51.13%)***</td>
<td>1.60%/(53.16%)***</td>
<td>(1.86%)/(6.67%)***</td>
<td>(0.82%)/(6.25%)</td>
</tr>
<tr>
<td>60</td>
<td>(0.63%)/(18.67%)***</td>
<td>1.49%/(1.59%)</td>
<td>0.29%/(2.68%)</td>
<td>0.90%/(47.35%)***</td>
<td>(0.13%)/(49.24%)***</td>
<td>(1.18%)/(4.04%)***</td>
<td>(0.20%)/(3.18%)</td>
</tr>
<tr>
<td>120</td>
<td>(0.20%)/(16.43%)***</td>
<td>1.11%/(1.11%)</td>
<td>1.68%/0.21%</td>
<td>0.13%/44.76%***</td>
<td>(0.52%)/(44.54%)***</td>
<td>(0.70%)/(2.49%)</td>
<td>(0.34%)/(2.25%)</td>
</tr>
<tr>
<td>360</td>
<td>(0.55%)/(15.94%)***</td>
<td>1.63%/(0.17%)</td>
<td>1.68%/0.37%</td>
<td>0.62%/37.28%***</td>
<td>(0.45%)/(37.36%)***</td>
<td>(0.21%)/(1.50%)</td>
<td>0.06%/(1.11%)</td>
</tr>
<tr>
<td>720</td>
<td>(0.47%)/(15.83%)***</td>
<td>1.58%/0.18%</td>
<td>1.74%/0.58%</td>
<td>0.66%/34.37%***</td>
<td>(0.35%)/(34.66%)***</td>
<td>(0.08%)/(1.30%)</td>
<td>0.09%/0.99%</td>
</tr>
<tr>
<td>infinity</td>
<td>(0.45%)/(15.84%)***</td>
<td>1.58%/0.18%</td>
<td>1.83%/0.72%</td>
<td>0.69%/33.61%***</td>
<td>(0.34%)/(33.96%)***</td>
<td>(0.03%)/(1.23%)</td>
<td>0.25%/0.79%</td>
</tr>
</tbody>
</table>

**Note:** The recommendation effectiveness in Panel A and Panel B is calculated from the buy-and-hold abnormal return in a [-1, +1] window; Panel C and Panel D calculates the recommendation effectiveness in a [-1, +5] event window. The annualized alpha is calculated by the multiplication of 252 (the number of trading days per year) and the daily abnormal return from the Carhart Model. Numbers in the parentheses indicate negative value.

*** Significant at 0.01 level; ** significant at 0.05 level; * significant at 0.10 level.
### Table 5. Performance Evaluation for Conditional Investment Decision based on Analysts’ Historical Performance (Portfolio C)

**Panel A: Revision-Based Strategy (Alpha no cost/Alpha after cost)**

<table>
<thead>
<tr>
<th>Specified Holding Horizon</th>
<th>C1</th>
<th>C1_Q1</th>
<th>C1_Q2</th>
<th>C1_Q3</th>
<th>C1_Q4</th>
<th>C1_Q5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>30</strong></td>
<td>18.55%<em><strong>/7.17%</strong></em></td>
<td>4.86%(3.13%)</td>
<td>9.00%***/0.87%</td>
<td>9.94%***/0.69%</td>
<td>13.23%***/2.94%</td>
<td>17.10%***/5.45%</td>
</tr>
<tr>
<td><strong>60</strong></td>
<td>15.12%<em><strong>/6.74%</strong></em></td>
<td>3.82%(1.03%)</td>
<td>5.83%***/0.81%</td>
<td>6.89%***/1.71%</td>
<td>8.18%***/2.77%</td>
<td>11.21%***/4.10%</td>
</tr>
<tr>
<td><strong>120</strong></td>
<td>14.05%<em><strong>/6.85%</strong></em></td>
<td>2.67%(0.36%)</td>
<td>4.73%***/1.39%</td>
<td>6.16%***/3.03%</td>
<td>5.70%***/2.31%</td>
<td>6.63%***/2.32%</td>
</tr>
<tr>
<td><strong>360</strong></td>
<td>13.59%<em><strong>/6.73%</strong></em></td>
<td>2.21%(0.12%)</td>
<td>3.17%*/0.82%</td>
<td>5.99%<em><strong>/3.68%</strong></em></td>
<td>4.19%***/1.91%</td>
<td>5.02%***/2.18%</td>
</tr>
<tr>
<td><strong>720</strong></td>
<td>13.49%<em><strong>/6.65%</strong></em></td>
<td>2.39%*/0.47%</td>
<td>3.05%*/0.86%</td>
<td>5.67%<em><strong>/3.60%</strong></em></td>
<td>4.13%***/2.08%</td>
<td>4.58%***/2.10%</td>
</tr>
<tr>
<td><strong>infinity</strong></td>
<td>13.44%<em><strong>/6.62%</strong></em></td>
<td>2.36%*/0.52%</td>
<td>3.07%*/0.91%</td>
<td>5.69%<em><strong>/3.66%</strong></em></td>
<td>3.91%***/1.94%</td>
<td>3.54%***/1.32%</td>
</tr>
</tbody>
</table>

**Panel B: Revision-Based Strategy (Alpha no cost/Alpha after cost)**

<table>
<thead>
<tr>
<th>Specified Holding Horizon</th>
<th>C2</th>
<th>C2_Q1</th>
<th>C2_Q2</th>
<th>C2_Q3</th>
<th>C2_Q4</th>
<th>C2_Q5</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>30</strong></td>
<td>18.37%<em><strong>/7.08%</strong></em></td>
<td>7.80%*/(0.33%)</td>
<td>10.61%***/1.55%</td>
<td>9.82%***/0.73%</td>
<td>10.35%***/0.06%</td>
<td>13.24%***/3.28%</td>
</tr>
<tr>
<td><strong>60</strong></td>
<td>15.00%<em><strong>/6.68%</strong></em></td>
<td>4.74%*/0.04%</td>
<td>7.03%***/1.79%</td>
<td>6.56%***/1.53%</td>
<td>5.95%***/0.16%</td>
<td>7.70%***/1.88%</td>
</tr>
<tr>
<td><strong>120</strong></td>
<td>13.93%<em><strong>/6.78%</strong></em></td>
<td>2.73%(0.43%)</td>
<td>4.72%***/1.21%</td>
<td>4.59%***/1.53%</td>
<td>4.71%***/1.13%</td>
<td>5.36%***/1.71%</td>
</tr>
<tr>
<td><strong>360</strong></td>
<td>13.48%<em><strong>/6.67%</strong></em></td>
<td>2.24%(0.03%)</td>
<td>3.93%***/1.48%</td>
<td>2.63%*/0.48%</td>
<td>3.36%***/0.97%</td>
<td>4.25%***/1.82%</td>
</tr>
<tr>
<td><strong>720</strong></td>
<td>13.38%<em><strong>/6.59%</strong></em></td>
<td>2.52%*/0.43%</td>
<td>4.08%***/1.81%</td>
<td>2.76%*/0.75%</td>
<td>3.08%***/0.95%</td>
<td>3.87%***/1.67%</td>
</tr>
<tr>
<td><strong>infinity</strong></td>
<td>13.33%<em><strong>/6.55%</strong></em></td>
<td>2.43%*/0.42%</td>
<td>3.96%***/1.73%</td>
<td>2.59%*/0.62%</td>
<td>3.08%***/1.02%</td>
<td>3.71%***/1.62%</td>
</tr>
</tbody>
</table>

**Note:** The recommendation effectiveness in Panel A and Panel B is calculated from the buy-and-hold abnormal return in a [-1, +1] window; *** Significant at 0.01 level; ** significant at 0.05 level; * significant at 0.10 level.
Figure 1(a). Rating-Based Portfolio Value Growth, Assuming $1 Initial Investment from Jan-1998 through Dec-2015

Figure 2(b). Revision-Based Portfolio Value Growth, Assuming $1 Invested from Jan-1998 through Dec-2015
Note: The value of the portfolios are calculated based on a $1 initial investment on 1998/1/8, and the capital value of the portfolio accumulates through 2015/12/31. The illustrated portfolios are designed to follow a long-only strategy with no delayed actions and infinity holding period. Both rating-based portfolio and revision-based portfolio use a daily market-value weight rebalancing schema.
Allocation of Resources to Combat Impacts of Diabetes: A Hybrid Approach to Maximize Human Health Using Data Classification

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Abstract

In 2016, 415 million people worldwide suffered with Diabetes disease, leading to approximately 5 million deaths and $673 billion to $1.197 trillion in global healthcare spending. The problem is growing rapidly – by 2040, diabetes will affect an estimated 640 million people. The chronic nature of diabetes and the alarming grow of incidents pose significant economic challenges to nations around the world, including direct costs such as inpatient hospital care and medication and indirect costs such as the loss of productivity and GDP. This study addresses the significant burden diabetes imposes on societies and measures the impact though multiple metrics. We use data mining techniques namely data categorization and classification to classify countries and advise best strategies for every classification. We propose a hybrid strategy for allocation of resources in order to maximize mitigation of the effects of the disease.
COMPARISON OF ALTERNATIVE MODELING METHODS FOR THE OPERATING ROOM SCHEDULING PROBLEM WITH SEQUENCE DEPENDENT SETUP TIMES

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ABSTRACT
Operating room management is one of the most important subjects of a hospital. One of the major concerns in operating room management is scheduling of surgical operations to operating rooms. In this study a real-life operating room scheduling problem with sequence dependent setup times is considered. A scheduling model using the scheduler module of OPL optimization software is developed. The model is solved for 10 days of real data and compared with the two previously developed approaches.

Keywords: Operating Room Scheduling, Sequence Dependent Setup Times, Integer Programming, Constraint Programming.

1. Introduction
Surgical unit is the most important and most costly unit of a hospital. In order to meet the increasing demand for health care services and reduce costs to improve quality of care, high usage rate must be assured for the surgical unit of a hospital. In order to provide higher utilization rates of surgical units, scheduling of operating rooms (ORs) should be done effectively. Inefficient or inaccurate scheduling of OR time often results in delays of surgery or cancellations of procedures, which are costly to the patient and the hospital. This study deals with OR scheduling process of a university hospital in Turkey. In this paper, an alternative model is developed using OPL Studio 3.7 (ILOG, 2003) to the integer programming (IP), constraint programming (CP) models previously developed in Ozkarahan et. al. (2009). The model developed simultaneously allocates operations to ORs and determines their sequence. The model developed considers two different objective functions. The first one is the utilization of ORs and the second objective function is maximizing weighted number of scheduled operations where the weights (priorities) are the urgencies of operations. Furthermore, the operating room scheduling problem contains sequence dependent setup times in its nature. Setup times in between surgical operations consist of cleaning operations.

* Corresponding author
and movement and fixture of any necessary equipment for the next operation (some
equipments may be transferred in between operating rooms).

The performance of the proposed model is compared with the IP and CP models given in
Ozkarahan et al. (2009) on 10 days real data in terms of both solution quality and solution
time for both of the objective functions: maximizing the total utilization of ORs and
maximizing weighted number of scheduled operations.

In the university hospital under study, there are seven common ORs used by eight
specialties. This paper deals with allocation of surgical operations belonging to these eight
specialties among the seven ORs used in common. About 40 operations are carried out daily
in the overall.

2. Proposed Solution Method: Scheduling Model with OPL Scheduler

In this paper, an alternative modeling approach is presented to the two models developed in
Ozkarahan et. al. (2009). The models presented in Ozkarahan et. al. (2009) are IP and CP
models whereas the new approach developed employs the scheduler module of OPL Studio
3.7 (ILOG, 2003).

Within the hospital, the minimum and the maximum setup times between two operations
are 30 minutes and 75 minutes respectively. Therefore, setup times are assumed to be
distributed uniformly between 30 and 75 minutes. So, for each setup time, a random value is
generated considering the uniform distribution with 30 and 75 minutes of boundaries. These
values are included in the mathematical models with $s_{ij}$ (setup time for operation $j$ when it
immediately follows operation $i$) variable.

OPL optimization software offers OPL scheduler module in which it supports scheduling
applications (ILOG, 2003). When a model is written using the reserved words for OPL
scheduler, OPL Studio directly identifies it and uses scheduler module to solve the model.
The most important advantage of this module that scheduling notions such as precedence
constraints, sequencing, resource usages can be easily defined with reserved words. The
reader may refer to ILOG OPL Language Manual (ILOG, 2003) for the details of the
scheduling module.

The main concept in scheduling module is the notion of activity, which is the association
of two integer variables: a starting date and a duration. In other words activity is a job to be
scheduled with a starting date and a given duration which leads to an ending date. It is defined
as follows:

$$\text{Activity } Operation, \ (p)$$

(1)
The activity in equation 1 stands for the operations to be scheduled to operating rooms. Each activity \( i \) is associated with duration of \( p_i \).

In addition to activities, resources which are used or consumed by activities can be defined in OPL scheduler. A unary resource is one that cannot be shared by two activities; i.e., as soon as an activity requires a resource, for a time interval, no other activity can use it during the same time interval (ILOG, 2003). In the problem under study, operating rooms including the dummy room (where unassigned operations will be put in) is defined as a unary resource as in Equation 2.

\[
\text{UnaryResource } \text{Room}[1..M+1] \tag{2}
\]

Setup times can be specified between any two activities requiring the same unary and state resource in OPL scheduler. Given two activities \( a \) and \( b \), the transition time between \( a \) and \( b \) is the amount of time that must elapse between the end of \( a \) and the beginning of \( b \) when \( a \) precedes \( b \). Transition times are specified in two steps in OPL. First, every activity involving transition times must be associated with a transition type. Second, the unary resource must be associated with a transition matrix that, given two transition types, returns a transition time (ILOG, 2003). In order to associate setup times with each activity the following definitions are necessary:

\( \text{TrType} \): Transition type associated with the activity = \( \{1,2,3,\ldots,N\} \).

\( \text{Setup}_{ij} \): Setup time when activity \( i \) precedes activity \( j \). \( (i=1,\ldots,N; j=1,\ldots,N; i\neq j) \)

Then the activity definition in equation 1 is turned into as in equation 3 below.

\[
\text{Activity } \text{Operation}_i \quad (p_i) \quad \text{transitionType } \text{TrType}_i \tag{3}
\]

Then the operating room scheduling model is developed in OPL scheduler.

\textit{Sets (Ozkarahan et. al. 2009)}

\( i = \) set of surgical operations, \( i=0..N \), where \( N \) is the number of surgical operations.

\( m = \) set of operating rooms, \( m=1..M \), where \( M \) is the number of operating rooms.

\( k_s = \) set of surgical operations \( i \) specifying operations of surgical specialty \( s \); \( s = 1, \ldots, G \); where \( G \) is the number of specialties

\( e_i = \) the set of operating rooms \( m \) of suitable ORs that surgical operation \( i \) can be assigned.

\( icu_f = \) set of surgical operations \( i \) specifying cases that need intensive care after surgery in intensive care unit of specialty \( f \). \( f = 1\ldots F \), where \( F \) is the number of intensive care specialties.
**Parameters (Ozkarahan et. al. 2009)**

\[ p_j = \text{processing time of operation } j. \]

\[ TOR = \text{amount of time OR is available per day}. \]

\[ Z_i = \text{weight assigned to operation } i. \]

\[ TS_s = \text{amount of OR time reserved for surgical specialty } s \text{ per day}. \]

\[ B_f = \text{number of intensive care beds available in Intensive Care Unit (ICU)} \ f; \ f = 1, \ldots, F, \text{ where } F \text{ is the number of intensive care specialties}. \]

\[ A = \text{a very big value}. \]

In addition to these definitions, sets, parameters and one more decision variable is defined.

**Decision Variable (Ozkarahan et. al. 2009)**

\[ X_{im} = \begin{cases} 1 & \text{if operation is assigned to room } m \\ 0 & \text{otherwise} \end{cases} \]

**Similar to the IP and CP approaches (Ozkarahan et. al., 2009), two objective functions are experimented independent from each other. These are given in Equations 4 and 5 which are maximizing the utilization of operating rooms and maximizing the weighted number of operations scheduled respectively.**

Maximize \[ \sum_{i=1}^{N} \sum_{m=1}^{M} X_{im} P_i \] (4)

Maximize \[ \sum_{i=1}^{N} \sum_{m=1}^{M} X_{im} Z_i \] (5)

The constraints of the system are given in the following:

\[ \sum_{m=1}^{M+1} X_{im} = 1; \quad i = 1, \ldots, N \] (6)

\[ \sum_{m \in C_i} X_{im} = 0; \quad i = 1, \ldots, N \] (7)

\[ \sum_{i \in S_s} \sum_{m=1}^{M} X_{im} P_i \leq TS_s \quad s = 1, \ldots, g. \] (8)

\[ \sum_{i \in ICU_f} \sum_{m=1}^{M} X_{im} \leq B_f \quad f = 1, \ldots, F \] (9)

**Operation requires(\(X_{im}\)) Room\(_m\) \quad i = 1, \ldots, N, m = 1..M+1** (10)
Constraint 6 states that each activity must be assigned to an operating room. One should note that it is assigned to either the dummy room $M+1$ (which means in fact it will not be performed) or one of the real operating rooms. Constraints 7, 8 and 9 are the eligibility, total time availability of specialties and intensive care constraints, respectively. Constraints 12 define the domain of the variable.

Constraints 10 and 11 make use of the OPL scheduler module. Constraint set 10 states that each operation requires the operating room in which it is assigned to. During this time, no other operations can be performed in the same room. In other words, this constraint avoids overlaps. In addition, it also builds the relationship between the $X$ variable and activities. That is:

If $X_{im}=0$ then Operation $i$ requires 0 units of Room $m$.

If $X_{im}=1$ then Operation $i$ requires 1 unit of Room $m$.

Constraint 11 states that ending time of each activity assigned to a real OR should be less than the time OR is available. If the activity is assigned to the dummy room then there is no restriction on the ending time of the activity (i.e. it is less than a big value $A$).

As it can be seen OPL scheduler gives the ability to define many of the constraints more easily and more compact form in scheduling applications. Furthermore a search procedure is included so that the solution will be obtained much faster. The search procedure written considering the first objective function is as follows:

- **Search Procedure 1:**

  search {
  forall(i ∈ {1..N} ordered by decreasing $p_i$)
  tryall(m ∈ {1..M+1} ordered by decreasing $m$)
  "$X_{im}=1" ;
  };

This search procedure states to

1. list all operations in the decreasing order of duration
2. list all operating rooms in the decreasing order.
3. try $X_{im}=1$ taking $i$ and $m$ from the corresponding lists.
The procedure goes on until a feasible solution is reached and then the search starts all over again for another feasible solution which performs better in objective function. This search procedure is expected to work well for the first objective function since the operations are listed according to their durations from the highest to the lowest. For the second objective function a similar search procedure is written where operations are listed from highest to lowest according to their urgency weights.

- **Search Procedure 2:**

```plaintext
search {
    forall(i ∈ {1..N} ordered by decreasing Z_i)
    tryall(m ∈ {1..M+1} ordered by decreasing m)
    X_{im}=1 ;
}
```

### 3. Computational Results and Discussion

In this study, 10 days data is considered which was also considered in Ozkarahan (2000). Computational results can be seen in Tables 1 and 2 for the two objective functions considered respectively. IP and CP models are implemented in ILOG OPL 5.5™ optimization software (ILOG, 2007) (Ozkarahan et. al., 2009), while the scheduling model is implemented in ILOG OPL Studio 3.7 optimization software (ILOG, 2003).

In addition, the solution times can also be seen in Table 1 and Table 2. Firstly, the solutions given in Tables 1 and 2 are the best solutions achieved within 600 seconds time limit. It should be noted that optimum solutions could not be obtained in any of the problems within this time limit.

Secondly, looking at Tables 1 and 2, it can be noticed that the scheduling model achieves the best objective values for the first function whereas it achieves the worst values for the second objective. This can be interpreted as the search procedure written for the first objective works very well. However, search procedure for the second objective did not suit the characteristic of the problem.
Table 1. Computational Results on OR utilization

<table>
<thead>
<tr>
<th>Test Inst.</th>
<th>IP MODEL</th>
<th>CP MODEL</th>
<th>Scheduling MODEL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Obj. Value*</td>
<td>Utilization (%)</td>
<td>CPU Time (s) to Reach the Best Solution*</td>
</tr>
<tr>
<td>1</td>
<td>559</td>
<td>83.18</td>
<td>350.38</td>
</tr>
<tr>
<td>2</td>
<td>542</td>
<td>80.65</td>
<td>564.25</td>
</tr>
<tr>
<td>3</td>
<td>543</td>
<td>80.80</td>
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<tr>
<td>4</td>
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</tr>
<tr>
<td>6</td>
<td>556</td>
<td>82.74</td>
<td>584.26</td>
</tr>
<tr>
<td>7</td>
<td>534</td>
<td>79.46</td>
<td>193.17</td>
</tr>
<tr>
<td>8</td>
<td>562</td>
<td>78.74</td>
<td>336.94</td>
</tr>
<tr>
<td>9</td>
<td>564</td>
<td>83.93</td>
<td>591.53</td>
</tr>
<tr>
<td>10</td>
<td>570</td>
<td>84.82</td>
<td>542.33</td>
</tr>
</tbody>
</table>

*: The findings in these columns are from Ozkarahan et. al. (2009)

Table 2. Computational Results on weighted number of scheduled operations

<table>
<thead>
<tr>
<th>Test Inst.</th>
<th>IP MODEL</th>
<th>CP MODEL</th>
<th>Scheduling MODEL</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Obj. Value*</td>
<td>CPU Time (s) to Reach the Best Solution*</td>
<td>Obj. Value*</td>
</tr>
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<td>123</td>
</tr>
<tr>
<td>3</td>
<td>109</td>
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<tr>
<td>5</td>
<td>100</td>
<td>9.83</td>
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<td>6</td>
<td>116</td>
<td>305.16</td>
<td>114</td>
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<td>7</td>
<td>118</td>
<td>94.45</td>
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<tr>
<td>8</td>
<td>118</td>
<td>108.52</td>
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<td>115</td>
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<td>105</td>
</tr>
<tr>
<td>10</td>
<td>114</td>
<td>115.86</td>
<td>112</td>
</tr>
</tbody>
</table>

*: The findings in these columns are from Ozkarahan et. al. (2009)

For OR utilization, neither IP model nor CP model is dominant over the other. However, scheduling model overperforms both IP and CP models and produces the best results (Table 1). On the other hand, in terms of second objective function, (see Table 2), IP model produces the best results for 6 out of 10 problems. For the other problems CP model gives better results for two of them and CP and IP approaches achieve the same objective value for the other two problems. When CPU times are compared it is seen that CP approach performs better.
6. Conclusion

In this paper, the proposed scheduling model in OPL, are compared to two optimization models, IP and CP for solving the OR scheduling problem of a university hospital in Turkey. Sequence dependent preparation times between operations are also considered. Two alternative objective functions are examined: maximizing utilization of ORs and maximizing the weighted number of scheduled operations where weights represent the urgencies of operations.

The computational results on 10 days of real data showed that, for the first objective (utilization of ORs) OPL scheduling model performs the best with no question both in terms of solution quality and solution time. However, for the second objective function the search procedure written for scheduling model has failed. For the second objective, IP approach performed better 6 out of 10 test problems. However, in case CP is not trapped to local optimum, it dominates IP in terms of both solution quality and solution time.

Acknowledgements

Part of this study has been carried out when the authors were with Dokuz Eylul University, Izmir, TURKEY.

References

Identifying Potentially Fraudulent Reporting, A Veterans Health Administration Case Study

Problem.

- Fraud can destroy an organization and go undetected for years. [1]
- Large organizations such as the Center for Medicare and Medicaid have increasingly been turning to automated fraud detection. [2]
- A Veterans Administration Inspector General report alleges that Veteran Health Administration (VHA) employees engaged in fraudulent reporting by failing to treat veterans in a timely fashion in order to manipulate performance metrics. [3]
- The implication is that Pay for Performance (PFP) initiatives were partially to blame for the allegedly fraudulent reporting. [3]
- There are allegations of continued fraudulent reporting at the VHA. [4]
- Use of several classes of machine learning models (both supervised and unsupervised) may help organizations detect fraudulent reporting (financial or otherwise). [5]

Data and Methods.

- Data: Publicly available data from the Veterans Health Administration. [6, 7]
- Variables of Interest: Access, quality, and cost metrics
- Example Models:
  - Bayesian learning models
  - Zero-Inflated models
  - Neural Network models
  - Random Forests
  - Other Ensemble Models
- Evaluation of Models
  - Cross-Validation (k-fold)
  - Training / Validation / Test Sets
  - Model Performance Metrics (No Fraud Allowed!)
- Tools of the Trade: Software Supporting Fraud Detection
  - R and R Studio Software [8]
  - Python [9]
Results

- Model selection varies based on response variable.

- The models identify specific observations which may indicate reporting that is fraudulent.

Relevance and Utility.

- Boards, management, and accounting firms are increasingly held responsible for fraudulent activity that occurs under their auspices under the Sarbanes-Oxley Act of 2002.

- Building these types of detection models makes sense for protection of the organization and its stakeholders.

- Leaders and managers in all sizeable organizations should be interested in the analysis and the tools provided.


Extended abstract

Managing patient flow in Resource-Patient-Centric environments using Theory of Constraints Logistic applications

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Professor of Management
Saginaw Valley State University

Effective healthcare facilities are an essential element of any society. In addition to providing care to the population in general, healthcare facilities many times ensure access to care for vulnerable populations, including the indigent, the uninsured, and the homeless. For these reasons, the health of our nation’s healthcare facilities is an important public issue. Given the challenges healthcare systems are facing worldwide, the design and dissemination of methodologies to better manage healthcare facilities are an important contribution to knowledge.

In this abstract, the focus is on Resource-Patient-Centric environments where the critical resource of the system can be easily identified. To manage this types of environment, the critical resource is usually closely scheduled and monitored because it determines the overall output of the system. An example of this type of environments is primary care, which can include family practice, pediatrics, and internal medicine. Specialty care such as cardiology, dermatology or oncology, can also be considered Resource-Patient-Centric. In these two cases, physicians are normally the critical resource of the system. Environments where physical resources, such as Operating Rooms and MRIs, are critical also satisfy the characteristic of Resource-Patient-Centric environments.

Resource-patient centric environments lend themselves to be managed using the Theory of Constraints methodology referred to as Drum-Buffer-Rope (DBR). The primary assumption to apply the DBR methodology is that the output of a system is determined by how its most critical resource is managed which is exactly the situation being discussed here. The Drum is the schedule of the critical resource and sets the pace for the overall system. Strategies to schedule the Drum in the case of Resource-Patient-Centric environments should take into account common problems in this environment such as no-shows and cancellations.

To protect from variability, Buffers—the second component of DBR—are used. Two different types of buffers include time and stock buffers. In a time buffer, activities are started early enough to protect the critical resource from disruptions. Stock buffers ensure availability of vital resources with the same idea of protecting critical resources. A special case for buffers is the “complete kit” which ensures that all required components are readily available at the location of service. These buffers must be designed and placed strategically within the system to provide maximum protection against variability at the least possible cost. Examples of buffers in a Resource-Patient-Centric environment includes the number of examination rooms in a Primary Care office and the rapid replenishment patient list to minimize the impact of cancelations.

While Buffers ensure that the drum is protected from variation, the Rope—the last component of DBR—is designed to ensure that buffers are not too long, too short or excessive. The rope is the schedule of
when work is to be released into the system. It prevents overload which can result in increased chaos. In a Resource-Patient-Centric environment, the rope represents the time patients are told to arrive.

During execution of the plan, TOC uses Buffer Management (BM) to synchronize efforts. BM monitors buffers levels and assigns a color based on their current levels. Traditionally, three or four colors (Black, Red, Yellow and Green) are used to classify buffer levels. The colors of all buffers are communicated to the personnel associated with or responsible for that buffer. They, then, use the color scheme to execute their tasks.

The presentation includes two case studies of applications of TOC in different clinics.
The demand for safe and high quality care among different stakeholders has been increasing all over the world. To meet this demand, healthcare providers seek for effective methodologies that improve the decision making process in administrative and clinical operations. Hospital length of stay (LOS) is a common measure of the efficiency of healthcare services. Monitoring and predicting patients’ LOS is important in assessing healthcare quality, resource allocation and costs. Unnecessary and unjustified increases in the LOS can be costly for both hospitals and patients.

In this study, we examine the use of statistical process control (SPC) techniques to identify abnormal LOS for individual patients. The identification of abnormal LOS for individual patients is comprised of several steps. First, we propose the use of the difference between the observed and expected (O-E) LOS as the performance metric of interest. This serves two purposes: (a) it allows us to risk-adjust the LOS to account for severer cases; and (b) allows to utilize the medical/financial models that identifies what is an expected LOS for each patient. Thus, a positive O-E LOS would indicate that a patient has stayed longer than expected. Second, we explore the use of parametric approaches to model the distribution of our O-E LOS, and we use Phase I control charting to ensure that there are no change-points within our baseline data. Once the baseline is established, our third step involves the development of real-time surveillance schemes for rapid identification of changes in the delivery process. These three steps capture the fault detection component of our proposed approach. We then use lean engineering principles to provide practitioners with quest into potential reasons for this deteriorated performance.

We apply our proposed approach on data, 167 patients (\(\bar{X}=2.92\) days, \(\sigma = 3.24\) days), captured in cardiology clinic in a large hospital in Virginia, USA. Outcomes of this study may help improve healthcare delivery processes in cardiology clinics that may lead to patients’ reduced length of stay.
Regional Hospital Quality Image and Competitive Strategy

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1 Hawk Drive, New Paltz, NY, USA

Abstract
This study analyzes the competitive environment of rural regional hospitals in two regions using secondary survey data provided by a healthcare organization. The goal is to understand the competitive advantages of individual hospitals from examining the quality perceptions of the general public toward a hospital’s overall image and its specialty services. As the data set does not contain all pertinent questions necessary to grasp the whole competitive environment, this study applies statistical approaches based on Markov Chain Monte Carlo (MCMC) methods to compare differences in general hospital quality perceptions and their implications in the specialty service quality perception. The result supports two major trends found in the hospital competitive strategy literature, namely, the challenges of urban/suburban hospitals moving into rural areas and the expansion of regional hospitals in specialty services.

Key words: hospitals, competitive strategy, MCMC, halo effect

1. Introduction
We obtained summary level quality perception survey data, containing survey results collected in 2013 and 2016 from two rural markets served by two hospital systems. To disguise the identities of the hospitals, we call the two regions, the north region and the south region, and the two hospital systems, System D and System W. Each system operates one hospital in each region. System D is a regional system while System W is based on a suburban area and acquired the two regional hospitals in recent years. The four hospitals are thus coded as DN, DS, WN, and WS. The first letter represents the hospital system, either D or W, and the second letter indicates the region, north or south. DN is the smallest hospital among the four with less than 100 hospital beds. The remaining three are 300–50 bed hospitals.

There are two main reasons for studying the four hospitals. The first is the availability of the secondary data provided and the second is that the competitive environment in the two regions reflects the major trends in the broader rural market. Mergers and acquisitions (M&As) of hospitals peaked in the 1990s. The Affordable Care Act reignited the M&A activities with a new trend of big urban/suburban players expanding into rural areas through M&As. The two systems, one independent and one acquiree, provide a good setting for comparison.

The original surveys were conducted over the phone to the regional residents in the October of 2013 and 2016. As the survey is relatively long and include some healthcare service questions which might be either ambiguous to the respondents or difficult for them to answer, we expect noise in the data. In addition, the answers may also be affected by the halo effect, where
respondents’ answers to individual questions are highly correlated through a general impression of a broader question. For example, when a respondent considers a hospital as a good quality hospital, she/he may answer favorably to the quality of specialty service provided by the same hospital without exercising her/his independent judgement. The goal of the study is to understand how local residents perceived the quality of the hospitals and how the perception reflects the competitive strategy of the hospitals.

2. Review of Literature

Healthcare organization M&As in the 1990s produced less than desirable results due to the lack of good risk assessment, while the recent round of M&As triggered by the Affordable Care Act has a better chance of success due to the availability of better tools and data (Gottlieb & Pilch, 2014). The reasons driving this wave of M&As also include (1) the expected lower payment rates, (2) higher operating cost due to increases on compliance, technology, and physician employment, and (3) the reward system in favor of the accountable care organization (ACO) model (Brown et al, 2012). A study of earlier M&A cases in California indicated no positive impact on operating efficiency and quality of care as a result of the increased size of the entities (Ho & Hamilton, 2000).

The prediction made in early 2000s foresaw a drive of M&As targeting rural hospitals, in particular, investor-owned companies targeting not-for-profit rural hospitals (Reilly, 2003). Another study concluded that rural hospitals with weaker financial performance and lower personnel cost are more attractive targets for M&As (Noles, et al., 2015). The same study also showed that even though M&As gave an opportunity for the rural hospitals to continue serving the healthcare needs of the communities, there were no significant changes in the operation scale and financial structure before and after the M&A.

When surveying customer’s satisfaction or perception among multiple attributes, a general concern is the halo effects, leading to higher correlations between attribute ratings. For example, respondents’ overall perception about a brand or one particular attribute of the brand may affect their ratings on other attributes (Leuthesser, Kohli & Harich, 1995; Wirtz & Bateson, 1995). The majority of previous studies in halo effects concentrated on employee performance assessment rating using multiple items, where the rater’s overall impression about a subject causes the high correlation and hinders the effort to identify weak areas for further improvement. Common treatment to the halo effect includes approaches such as correlations, regression, and principal component analysis to isolate the common effect (Myers, 1965; Landy, Vance, Barnes-Farrell & Steele, 1980; King, Hunter & Schmidt, 1980; Murphy, 1982). We expect the same effect also appeared in the healthcare survey data we obtained. However, the survey questions are a mix of quality rating and hospital selection questions. For example, in one question, respondents were asked to rate 15 hospitals using a scale of one to five while other questions asked which hospital they would prefer for a particular service, either as an open-ended question or a choice from a given list. As such, the consideration of the halo effect is different from those in the traditional halo-effect literature.
3. Methodology

The two main research questions this study intends to address are:

(1) Are there differences in the overall quality perception between two competing hospitals serving the same region?

(2) Are there halo effects between the general quality perception of a hospital and its specialty service quality perceptions?

The first question investigates whether the relative quality perceptions of WN and WS have improved since their acquisition. The second question focuses on the new areas of growth, specialty services such as orthopedics, maternity, cardiology, and oncology. According to (Peterson & Lovrien 2010), the development of specialty services provides growth opportunities for regional referral hospitals, mainly in the 175 to 350 bed-size hospitals. The main challenges of developing these specialty services came not only from the competition among regional players, but also from prestigious urban center hospitals within a 2-hour driving distance.

To answer the two questions, we focus on two survey questions. The first one (Q1) is a general quality rating question on a 5-level Likert scale, an ordinal or interval variable. The second (Q2) one is the choice of hospitals for each of the specialty services, a nominal variable. The first question is converted to a nominal scale by counting the number of participants giving a favorable rating of four or five (top-two level rating).

We use another two questions to consider the halo effect. Since the choice of hospital service in rural areas is often affected by the distance to the hospitals (Hogan, 1988), we include another question (Q3) which asked the participants to pick a hospital which is the most convenient to them in terms of the distance to the hospital. Another question (Q4) asked the participants to come up with the name of a hospital in their region they considered as a good quality hospital. This is an open-ended question and is the first question after the initial set of screening questions to determine the eligibility of the respondents to participate in the survey. For example, the survey excluded those who were employed by a healthcare organization or a marketing research firm.

Halo effect: Respondents are usually more familiar with hospitals in their neighborhoods and more likely to rate favorably for them. On the other hand, a hospital with higher perceived quality may also be perceived as the one conveniently located for them even though there is another hospital slightly closer to them. Table 1 and Table 2 below list the number of respondents in each region (1) perceived the hospital conveniently located for them (Q3), and (4) selected the same hospital as their good quality hospital. Because the two hospitals in the north region differ greatly in their sizes and are located across a river, the comparison is not as clear. However, the two hospitals in the south region have comparable sizes and are located very close to each other. Yet, a much larger number of respondents considered DS closer to them than WS. This shows the impact of quality perception on the distance perception. We also recognized that there was a higher percentage of people choosing their convenient hospitals as their good quality hospital. As a result, we use the distance-quality effect as a concept similar to the halo effect.
4. General quality perceptions

To compare the percentage of participants giving favorable ratings (4 or 5 in Q1) in each region, we conducted two Bayesian inferences using the Hamiltonian MCMC method adopted in RStan (RStan, n.d.). In each analysis, a beta distribution serves as the conjugate prior distribution for a binomial likelihood function. In the first inference, we assume no prior knowledge by using a uniform prior in the beta form of θ ~ Beta(1,1), while in the second round, we use the distance-quality counts as the beta prior. Each output table has three numerical rows, representing the posterior distribution of θ₁, θ₂, and θ₁ - θ₂, where θ₁ and θ₂ correspond to the parameters for the two hospitals of interest in Table 1 and Table 2. The columns include the mean, standard deviation, and 0.025, 0.25, 0.5, 0.75, 0.975 quantiles of each parameter.

4.1 2013 survey

Tables 3 to 6 contain the results obtained from 2013 survey data by the regions and the prior distributions.

Table 3: 2013 North Region (DN vs WN) - Uniform prior

<table>
<thead>
<tr>
<th></th>
<th>mean</th>
<th>sd</th>
<th>2.5%</th>
<th>25%</th>
<th>50%</th>
<th>75%</th>
<th>97.5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>θ₁</td>
<td>0.62</td>
<td>0.03</td>
<td>0.56</td>
<td>0.60</td>
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<td>θ₂</td>
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<td>0.39</td>
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<td>θ₁ - θ₂</td>
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<td>0.22</td>
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<td>0.35</td>
</tr>
</tbody>
</table>

Table 4: 2013 North Region (DN vs WN) – Distance-quality prior

<table>
<thead>
<tr>
<th></th>
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<th>sd</th>
<th>2.5%</th>
<th>25%</th>
<th>50%</th>
<th>75%</th>
<th>97.5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>θ₁</td>
<td>0.62</td>
<td>0.03</td>
<td>0.56</td>
<td>0.60</td>
<td>0.62</td>
<td>0.64</td>
<td>0.68</td>
</tr>
<tr>
<td>θ₂</td>
<td>0.37</td>
<td>0.03</td>
<td>0.32</td>
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<td>0.39</td>
<td>0.42</td>
</tr>
<tr>
<td>θ₁ - θ₂</td>
<td>0.25</td>
<td>0.04</td>
<td>0.17</td>
<td>0.22</td>
<td>0.25</td>
<td>0.28</td>
<td>0.33</td>
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</tbody>
</table>
Table 5: 2013 South Region (DS vs WS) - Uniform prior

<table>
<thead>
<tr>
<th></th>
<th>mean</th>
<th>sd</th>
<th>2.5%</th>
<th>25%</th>
<th>50%</th>
<th>75%</th>
<th>97.5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>θ1</td>
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<td>0.03</td>
<td>0.70</td>
<td>0.75</td>
<td>0.77</td>
<td>0.78</td>
<td>0.82</td>
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<tr>
<td>θ2</td>
<td>0.48</td>
<td>0.03</td>
<td>0.41</td>
<td>0.45</td>
<td>0.47</td>
<td>0.50</td>
<td>0.54</td>
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<tr>
<td>θ1-θ2</td>
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<td>0.04</td>
<td>0.20</td>
<td>0.26</td>
<td>0.29</td>
<td>0.32</td>
<td>0.38</td>
</tr>
</tbody>
</table>

Table 6: 2013 South Region (DS vs WS) – Distance-quality prior

<table>
<thead>
<tr>
<th></th>
<th>mean</th>
<th>sd</th>
<th>2.5%</th>
<th>25%</th>
<th>50%</th>
<th>75%</th>
<th>97.5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>θ1</td>
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<td>0.02</td>
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<td>0.41</td>
<td>0.46</td>
<td>0.48</td>
<td>0.50</td>
<td>0.54</td>
</tr>
<tr>
<td>θ1-θ2</td>
<td>0.31</td>
<td>0.04</td>
<td>0.24</td>
<td>0.29</td>
<td>0.31</td>
<td>0.34</td>
<td>0.38</td>
</tr>
</tbody>
</table>

4.2 2016 survey

Tables 7 to 10 contain the results obtained from 2016 survey data by the regions and the prior distributions.

Table 7: 2016 North Region (DN vs WN) - Uniform prior

<table>
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<tr>
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<th>sd</th>
<th>2.5%</th>
<th>25%</th>
<th>50%</th>
<th>75%</th>
<th>97.5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>θ1</td>
<td>0.63</td>
<td>0.03</td>
<td>0.56</td>
<td>0.60</td>
<td>0.63</td>
<td>0.65</td>
<td>0.69</td>
</tr>
<tr>
<td>θ2</td>
<td>0.24</td>
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<td>0.18</td>
<td>0.22</td>
<td>0.24</td>
<td>0.26</td>
<td>0.30</td>
</tr>
<tr>
<td>θ1-θ2</td>
<td>0.39</td>
<td>0.05</td>
<td>0.30</td>
<td>0.36</td>
<td>0.39</td>
<td>0.42</td>
<td>0.47</td>
</tr>
</tbody>
</table>

Table 8: 2016 North Region (DN vs WN) – distance-quality prior

<table>
<thead>
<tr>
<th></th>
<th>mean</th>
<th>sd</th>
<th>2.5%</th>
<th>25%</th>
<th>50%</th>
<th>75%</th>
<th>97.5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>θ1</td>
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<td>0.59</td>
<td>0.61</td>
<td>0.65</td>
</tr>
<tr>
<td>θ2</td>
<td>0.26</td>
<td>0.03</td>
<td>0.21</td>
<td>0.24</td>
<td>0.26</td>
<td>0.27</td>
<td>0.30</td>
</tr>
<tr>
<td>θ1-θ2</td>
<td>0.34</td>
<td>0.04</td>
<td>0.26</td>
<td>0.31</td>
<td>0.34</td>
<td>0.36</td>
<td>0.41</td>
</tr>
</tbody>
</table>

Table 9: 2016 South Region (DS vs WS) - Uniform prior

<table>
<thead>
<tr>
<th></th>
<th>mean</th>
<th>sd</th>
<th>2.5%</th>
<th>25%</th>
<th>50%</th>
<th>75%</th>
<th>97.5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>θ1</td>
<td>0.74</td>
<td>0.03</td>
<td>0.68</td>
<td>0.72</td>
<td>0.74</td>
<td>0.76</td>
<td>0.80</td>
</tr>
<tr>
<td>θ2</td>
<td>0.40</td>
<td>0.03</td>
<td>0.33</td>
<td>0.38</td>
<td>0.40</td>
<td>0.42</td>
<td>0.47</td>
</tr>
<tr>
<td>θ1-θ2</td>
<td>0.34</td>
<td>0.05</td>
<td>0.25</td>
<td>0.31</td>
<td>0.34</td>
<td>0.37</td>
<td>0.43</td>
</tr>
</tbody>
</table>

Table 10: 2016 South Region (DS vs WS) – distance-quality prior

<table>
<thead>
<tr>
<th></th>
<th>mean</th>
<th>sd</th>
<th>2.5%</th>
<th>25%</th>
<th>50%</th>
<th>75%</th>
<th>97.5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>θ1</td>
<td>0.76</td>
<td>0.02</td>
<td>0.71</td>
<td>0.74</td>
<td>0.76</td>
<td>0.77</td>
<td>0.80</td>
</tr>
<tr>
<td>θ2</td>
<td>0.40</td>
<td>0.03</td>
<td>0.34</td>
<td>0.38</td>
<td>0.40</td>
<td>0.42</td>
<td>0.47</td>
</tr>
<tr>
<td>θ1-θ2</td>
<td>0.36</td>
<td>0.04</td>
<td>0.27</td>
<td>0.33</td>
<td>0.36</td>
<td>0.39</td>
<td>0.43</td>
</tr>
</tbody>
</table>

Figure 1 to Figure 4 below plot the densities of θ1 - θ2 in Table 3 to Table 10. In all four figures, the beta density (distance-quality prior) is more concentrated than the corresponding uniform
density (uniform prior). The means of $\theta_1 - \theta_2$ between the two different prior distributions are very close to each other. The largest difference appears between Table 7 and Table 8 (Figure 3) for 2016 north region. This indicates the observed data are quite consistent with the general expectations of the distance-quality pattern.
5. Specialty Service Quality Perception: Between DS and WS

In the specialty service analysis, we focus on hospitals DS and WS in the south region because the other two hospitals in the north region have very different sizes. The small hospital does not provide the same breadth of specialty services. This analysis picks two specialty areas, cardiology and oncology. In each analysis, we again apply two different prior distributions. The first one is the uniform distribution as before and the second one is the beta posterior distribution obtained from the general perception analysis in the previous section. For example, in Tables 12 and 16, the beta priors for $\theta_1$ and $\theta_2$ are based on the posterior $\theta_1$ and $\theta_2$ obtained in Table 6. The beta priors for $\theta_1$ and $\theta_2$ in Tables 14 and 18 are obtained from the posterior $\theta_1$ and $\theta_2$ distributions in Table 10.

5.1 Cardiology:

Table 11: 2013 South Region (Cardiology) - Uniform prior

<table>
<thead>
<tr>
<th></th>
<th>mean</th>
<th>sd</th>
<th>2.5%</th>
<th>25%</th>
<th>50%</th>
<th>75%</th>
<th>97.5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\theta_1$</td>
<td>0.52</td>
<td>0.03</td>
<td>0.45</td>
<td>0.50</td>
<td>0.52</td>
<td>0.55</td>
<td>0.59</td>
</tr>
<tr>
<td>$\theta_2$</td>
<td>0.07</td>
<td>0.02</td>
<td>0.04</td>
<td>0.05</td>
<td>0.06</td>
<td>0.08</td>
<td>0.10</td>
</tr>
<tr>
<td>$\theta_1 - \theta_2$</td>
<td>0.46</td>
<td>0.04</td>
<td>0.39</td>
<td>0.43</td>
<td>0.45</td>
<td>0.48</td>
<td>0.53</td>
</tr>
</tbody>
</table>

Table 12: 2013 South Region (Cardiology) – Beta prior (Table 6)

<table>
<thead>
<tr>
<th></th>
<th>mean</th>
<th>sd</th>
<th>2.5%</th>
<th>25%</th>
<th>50%</th>
<th>75%</th>
<th>97.5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\theta_1$</td>
<td>0.66</td>
<td>0.02</td>
<td>0.61</td>
<td>0.64</td>
<td>0.66</td>
<td>0.67</td>
<td>0.70</td>
</tr>
<tr>
<td>$\theta_2$</td>
<td>0.27</td>
<td>0.02</td>
<td>0.23</td>
<td>0.26</td>
<td>0.27</td>
<td>0.28</td>
<td>0.30</td>
</tr>
<tr>
<td>$\theta_1 - \theta_2$</td>
<td>0.39</td>
<td>0.03</td>
<td>0.33</td>
<td>0.37</td>
<td>0.39</td>
<td>0.41</td>
<td>0.45</td>
</tr>
</tbody>
</table>

From observing the values in Table 11 and Table 12 for 2013 cardiology specialty, we noticed

1. the differences in the means of $\theta_1$ and $\theta_2$ are much higher than those in the general quality perception analysis (Tables 5 and Table 6).
2. the difference in the means of $\theta_2$ is particularly high.
3. the beta prior reduces the mean of $\theta_1 - \theta_2$ from 0.46 to 0.39.
4. the means of $\theta_1$ and $\theta_2$ in Table 6 are higher than those in Table 12.
5. the mean of $\theta_1 - \theta_2$ is higher in Table 10 comparing with that in Table 6.

The results indicate that the general quality perception of the hospitals does not transfer to the perception of the specialty service, especially for the lower general quality perception hospital, WS. Generally, it is harder to earn the trust or the familiarity of the residents in the specialty area. This is a common challenge when regional hospitals try to expand into specialty services. The 2016 data indicate a similar pattern.

Table 13: 2016 South Region (Cardiology) - Uniform prior

<table>
<thead>
<tr>
<th></th>
<th>mean</th>
<th>sd</th>
<th>2.5%</th>
<th>25%</th>
<th>50%</th>
<th>75%</th>
<th>97.5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\theta_1$</td>
<td>0.54</td>
<td>0.03</td>
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<td>0.54</td>
<td>0.56</td>
<td>0.61</td>
</tr>
<tr>
<td>$\theta_2$</td>
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<td>0.01</td>
<td>0.03</td>
<td>0.04</td>
<td>0.05</td>
<td>0.06</td>
<td>0.09</td>
</tr>
<tr>
<td>$\theta_1 - \theta_2$</td>
<td>0.49</td>
<td>0.04</td>
<td>0.42</td>
<td>0.46</td>
<td>0.49</td>
<td>0.51</td>
<td>0.56</td>
</tr>
</tbody>
</table>

7
Table 14: 2016 South Region (Cardiology) – Beta prior (Table 10)

<table>
<thead>
<tr>
<th></th>
<th>mean</th>
<th>sd</th>
<th>2.5%</th>
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<th>50%</th>
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</tr>
</thead>
<tbody>
<tr>
<td>$\theta_1$</td>
<td>0.65</td>
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<td>0.65</td>
<td>0.67</td>
<td>0.69</td>
</tr>
<tr>
<td>$\theta_2$</td>
<td>0.22</td>
<td>0.02</td>
<td>0.19</td>
<td>0.21</td>
<td>0.22</td>
<td>0.24</td>
<td>0.27</td>
</tr>
<tr>
<td>$\theta_1 - \theta_2$</td>
<td>0.43</td>
<td>0.03</td>
<td>0.36</td>
<td>0.41</td>
<td>0.43</td>
<td>0.45</td>
<td>0.49</td>
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</table>

Figure 5 and Figure 6 plot the densities of $\theta_1$ and $\theta_2$ in Table 13 and Table 14 respectively for 2016 cardiology perception. It is clear that the beta prior makes the shapes of the two densities in Figure 6 closer to each other than those in Figure 5.
5.2 Oncology:

Table 15: 2013 South Region (Oncology) - Uniform prior

<table>
<thead>
<tr>
<th></th>
<th>mean</th>
<th>sd</th>
<th>2.5%</th>
<th>25%</th>
<th>50%</th>
<th>75%</th>
<th>97.5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>θ₁</td>
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<td>0.23</td>
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</tr>
<tr>
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<td>0.03</td>
<td>0.05</td>
<td>0.06</td>
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<tr>
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<td>0.09</td>
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<td>0.15</td>
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</table>

Table 16: 2013 South Region (Oncology) – Beta prior (Table 6)

<table>
<thead>
<tr>
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<th>sd</th>
<th>2.5%</th>
<th>25%</th>
<th>50%</th>
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<th>97.5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>θ₁</td>
<td>0.50</td>
<td>0.02</td>
<td>0.45</td>
<td>0.48</td>
<td>0.50</td>
<td>0.52</td>
<td>0.55</td>
</tr>
<tr>
<td>θ₂</td>
<td>0.27</td>
<td>0.02</td>
<td>0.23</td>
<td>0.25</td>
<td>0.27</td>
<td>0.28</td>
<td>0.31</td>
</tr>
<tr>
<td>θ₁ - θ₂</td>
<td>0.23</td>
<td>0.03</td>
<td>0.17</td>
<td>0.21</td>
<td>0.23</td>
<td>0.25</td>
<td>0.30</td>
</tr>
</tbody>
</table>

For oncology specialty, a large number of respondents choose the prestigious hospital in the nearest major city. The quality image of this specialty area exhibits a similar but worse behavior than that of the cardiology quality image.

Table 17: 2016 South Region (Oncology) - Uniform prior (Table 10)

<table>
<thead>
<tr>
<th></th>
<th>mean</th>
<th>sd</th>
<th>2.5%</th>
<th>25%</th>
<th>50%</th>
<th>75%</th>
<th>97.5%</th>
</tr>
</thead>
<tbody>
<tr>
<td>θ₁</td>
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<td>0.19</td>
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<td>0.24</td>
<td>0.26</td>
<td>0.31</td>
</tr>
<tr>
<td>θ₂</td>
<td>0.05</td>
<td>0.01</td>
<td>0.02</td>
<td>0.04</td>
<td>0.05</td>
<td>0.06</td>
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</tr>
<tr>
<td>θ₁ - θ₂</td>
<td>0.19</td>
<td>0.03</td>
<td>0.13</td>
<td>0.17</td>
<td>0.20</td>
<td>0.22</td>
<td>0.27</td>
</tr>
</tbody>
</table>

Table 18: 2016 South Region (Oncology) – Beta prior

<table>
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<tr>
<th></th>
<th>mean</th>
<th>sd</th>
<th>2.5%</th>
<th>25%</th>
<th>50%</th>
<th>75%</th>
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</tr>
</thead>
<tbody>
<tr>
<td>θ₁</td>
<td>0.50</td>
<td>0.02</td>
<td>0.45</td>
<td>0.48</td>
<td>0.50</td>
<td>0.52</td>
<td>0.55</td>
</tr>
<tr>
<td>θ₂</td>
<td>0.22</td>
<td>0.02</td>
<td>0.18</td>
<td>0.21</td>
<td>0.22</td>
<td>0.23</td>
<td>0.26</td>
</tr>
<tr>
<td>θ₁ - θ₂</td>
<td>0.28</td>
<td>0.03</td>
<td>0.22</td>
<td>0.26</td>
<td>0.28</td>
<td>0.30</td>
<td>0.34</td>
</tr>
</tbody>
</table>

Again, the beta prior in Figure 8 brings the two density curves closer to each other in both the shape and distance than those in Figure 7.
6. Conclusion

This is a preliminary study attempting to utilize the given data set to draw inferences regarding the competitive standings of the four hospitals. The results indicate that the two struggling hospitals, WN and WS, are still rebuilding their quality images after the M&A. In addition, rural
referral hospitals engaging in expanding their specialty services face a difficult challenge building their reputations, especially when there are well known specialty hospitals in the nearest urban centers. The differences of $\theta_1$ and $\theta_2$ values generated by the uniform prior and the beta prior serve as indicators of quality perception gaps. The larger the gap, the more challenging it is to build the reputation in the area. Finally, the surveys measure resident’s quality perceptions, which may or may not translate into hospital selection when actual service is needed. Further analysis combining the perception data and market share data can provide a better picture of the competitive environment.

7. References


Structuring Corporate Prediction Market Incentives for a Maximized Internal Motivation

Abstract: Businesses require knowledge of the future to help ensure the best possible decisions are made, both strategically and operational. One tool which can be leveraged is a Corporate Prediction Market which may be able to overcome challenges associated with traditional knowledge sharing methods. Like knowledge sharing systems, corporate prediction markets benefit from having a variety of active participants. This paper explores how firms can best structure the markets to attract and maintain adequate participation levels, especially given the heterogeneous motivations of employees.
1. Introduction

The benefits of knowing the future before it happens are quite obvious. If businesses could know, with absolute certainty, what the future holds they would know where to build their next store front, when to launch a new offering and how much of a given product they will sell in a year. Firms could even identify the best exit strategy and timing. In industries which are greatly impacted by government regulation, knowing the outcome of political elections before the actual voting provides a massive competitive advantage. Businesses could easily position themselves for future success because they would consistently make the best decision. Of course, we do not have access to crystal balls and businesses, like individuals, are forced to wrestle with future uncertainty.

To best address these challenges companies employ a plethora of forecasting tools and techniques. On one end of the spectrum are the Big Data and Analytical approaches which rely on historical data to identify trends and patterns used to forecast the future. A classic example of this style of forecast is the “diapers and beer” type analysis which looks for events consistently occurring together (see Fu, Budzik, and Hammond (2000) for a detailed explanation). On the other end of the spectrum is what some call “intuition” based decision making where choices are made based on weak signals and “gut feel” (see Sadler-Smith and Shefy (2004) for a discussion). The analytical approach has been criticized for being backward looking and failing to forecast events which deviate significantly from expectation, or what Taleb (2007) called ‘black-swan’ events. On the other hand, the ‘gut-feel’ approach lacks the quantitative support found in the analytic-based approach. Between the two extremes lies a relatively new technique called Prediction Markets. In these markets, participants are able to act on their opinions, be they
intuition or data driven, and the pricing mechanism within the market aggregates the various opinions to produce a forecast of future events.

Historically, prediction markets, particularly those focused on U.S. Politics have proven to be wonderfully accurate (Berg, Forsythe, & Rietz, 1997). According to De Castro and Cramton (2009), “the overwhelming evidence suggest that prices in prediction markets do convey valuable information, in many different settings.” In order for firms to fully capitalize on the power of the market to aggregate information they must ensure an adequate number of traders (liquidity) within the market. Rieg and Schoder (2011) highlight maintaining engagement among participants as a key challenge for corporate prediction markets. Numerous academic and practitioner-based articles have been published reviewing and suggesting ways to attract and motivate traders within prediction markets (examples include: Leigh and Wolfers (2007); Luckner (2007); Servan-Schreiber, Wolfers, Pennock, and Galebach (2004); Slamka, Soukhoroukova, and Spann (2008)).

Tangent to the use of prediction markets for forecasting is the use of prediction markets to gather information. Maciejovsky and Budescu (2013) demonstrate the use of markets to overcome challenges associated with knowledge-sharing. Employees are reluctant to engage in knowledge sharing when it is costly for them to do so and they see limited personal benefit (Pee & Lee, 2015), or when there are conflicts between individual incentives and collective objectives (Maciejovsky & Budescu, 2013). Using a prediction market as a means for exchanging information addresses the issue of cost/benefit and misaligned incentives by creating a situation which requires participants to share their knowledge in order to maximize their personal gain (Maciejovsky & Budescu, 2013).
Corporate Prediction Markets face the challenge of a smaller pool of possible participants in comparison to the larger public prediction markets; essentially limiting themselves to individuals related to the firm (e.g., employees, partners, contractors). Adding to the challenge is the heterogeneously motivated workforce. On one end of the spectrum is a group of employees who will never engage in the prediction market, regardless of the incentive offered. On the other end is a group of employees who will gladly take on the task without asking anything in return. Our focus is the majority of employees somewhere between the two extremes that require some incentive to participate. We draw on prior work regarding intrinsic and extrinsic motivation, specifically Cognitive Evaluation Theory (CET) and incentives for knowledge sharing, to evaluate various programs designed to attract and engage participants in corporate prediction markets.

The rest of the paper is organized as follows: in section 2 we review prediction markets and corporate applications. In section 3 we review the literature on employee motivation with regard to knowledge sharing and CET. Section 4 discusses and evaluates incentive structures for Corporate Prediction Markets and we conclude in Section 5.

2. Prediction Markets

Prediction markets, like all markets, represent a collection of traders engaged in a series of buying and selling transactions. Specifically, prediction markets center on the exchange of securities structured such that their values are tied to the future outcome of an event. Given the relative newness of prediction markets, particularly outside the Economic literature, they warrant at least a brief discussion.
Prediction markets began gaining popularity in the 1980’s with the most famous market being the University of Iowa’s primarily focused on forecasting the outcome of political elections. Political elections provide a fairly straight-forward context illustrating prediction markets and their use. A common form of prediction markets is the winner-take-all market (WTA) where a security pays a predetermined amount if a given event occurs and pays nothing otherwise. In a winner-take-all market, the price of the security represents the market’s expectation regarding the probability of an event occurring (Wolfers & Zitzewitz, 2004). For example, starting November 19, 2014, the Iowa Electronic Market (IEM) run by the University of Iowa opened a winner-take-all market related to the 2016 US Presidential Election.\(^1\) Two securities were offered. The first paid $1 if the Democratic Party nominee receives the majority of votes cast for the two major parties, it pays $0 otherwise. The second security paid $1 if the Republican Party nominee received the majority of votes cast for the two major parties, it pays $0 otherwise. As of 10:15 am CST on November 5, 2016, the share that paid in the event the Democratic Party nominee received the most votes was trading around $0.69 and the share which paid in the event the Republican Party nominee received the most votes was trading around $0.33. This translated to a collective estimate of a 69% chance the Democratic Party nominee would receive the majority of votes while the Republican nominee had a 33% chance of receiving the majority of votes. It does not speak to the percentage of votes received by either party, but rather the likelihood a given party would receive the majority of the popular vote (as opposed to winning the Electoral College).

Markets like this have also been applied in corporate settings, with companies like Hewlett-Packard, Google and Best Buy using prediction markets for a variety of forecasting

\(^1\) http://tippie.uiowa.edu/iem/markets/pr_pres16_wta.html
purposes. The focus of prediction markets can range from sales forecasting to identifying new product release dates (Bothos, Apostolou, & Mentzas, 2008). In one of the most referenced corporate prediction markets (Thompson, 2012; Varma, 2013; Wolfers & Zitzewitz, 2004) Hewlett-Packard partnered with Caltech to explore information aggregation methods (Plott & Chen, 2002). A market aimed at forecasting future product sales, and structured in a winner-take-all format, ultimately produced predictions which were more accurate (closer to reality) than those generated by the ‘official’ forecasting team (Plott & Chen, 2002).

Another use case is highlighted in De Castro and Cramton (2009) where a prediction market is explored as a method for forecasting electricity demand. In other forecasting methods, select participants are asked their opinion of future demand. While this may result in the collection of valuable information, it is not guaranteed participants will be properly incentivized to disclose the best estimate (De Castro & Cramton, 2009). This forecasting of resource requirements can be extended beyond electricity and applied to a variety of key resources in a plethora of industries.

As per Rieg and Schoder (2011), “one of the most serious problems with [corporate prediction markets is] keeping up the motivation to participate, thus ensuring adequate trading volume.” Without enough liquidity the markets may ‘freeze’ and the pricing mechanism would fail to produce an informative price. To overcome this challenge, corporate prediction markets will need to ensure participants are motivated to engage for the duration of the market. Unlike a point-in-time survey, where opinions are collected and analyzed, a prediction market requires continued participation as traders adjust their holdings based on new information.

Various markets and experiments have leveraged different methods to maintain engagement, ranging from real money to grant-funding to leader boards and prizes. The well-
known Iowa Electronic Market allows participants to invest US currency but caps investment at $500 per individual (Berg & Rietz, 2006). In a market opened to pediatricians, nurses, microbiologist and others with presumed knowledgeable of Flu cases, traders were provided with $100 in ‘FLU’ currency and at the end of the experiment any FLU money they had accumulated was converted to educational grants at a rate of 1FLU:1USD (Polgreen, Nelson, Neumann, & Weinstein, 2007). Participants at Ford enjoyed earning bragging rights among their peers as well as being recognized via published results based on their success in internal prediction markets (Montgomery, Stieg, Cavaretta, & Moraal, 2013). At Google, employees reportedly were motivated by the t-shirts they could win by performing well in the market (Cowgill, Wolfers, & Zitzewitz, 2009).

Google runs what is believed to be the largest corporate prediction market and is open to active employees along with some contractors and vendors. (Cowgill et al., 2009). Cowgill et al. (2009) reported roughly 6,500 accounts with around 23% of those accounts placing at least one trade. In reporting on the markets at Google, Cowgill et al. (2009) take special care to highlight the employees participating in the market are not representative of the employee population. Participants had been with the company longer, were less likely to leave the firm, and were more embedded within the organization (Cowgill et al., 2009). The incentives offered appeared to only appeal to a subset of employees and many opted out participating.

Plott and Chen (2002) highlight the importance of selecting knowledgeable traders for corporate prediction markets to ensure those employees with the most valuable information are able to reveal it in the market. Christiansen (2012) found market performance improved with more traders. In general, more is better and corporate prediction markets benefit by including as many participants from as many segments of the company as possible. According to Servan-
Schreiber et al. (2004) to have an accurate prediction market “the essential ingredient seems to be a motivated and knowledgeable community of traders.” The diverse backgrounds suggest independent decision making and unique information both of which add to the strength of the forecast (Surowiecki, 2005). When generating a sales forecast there are many people outside of sales who potentially have some insight. It appears, at least in the example at Google, that the potentially most knowledgeable employees – those with the longest tenure and closest relationships – self-select into the market (Cowgill, Wolfers, & Zitzewitz, 2009). HP invited employees they felt would be knowledgeable into the market (Plott & Chen, 2002). Siemens ran a market with 50 developers working on a project aimed at predicting whether the project would complete on time (Buckley, 2016; Ortner, 1998). When explicitly inviting employees to participate there is a real risk of excluding knowledgeable traders.

Firms may opt to open the market to entire business units rather than select individuals for participation. While this approach helps reduce the risk of unintentionally excluding a potentially knowledgeable trader it carries the risk of employees not opting into the market. Firms will need to develop a comprehensive plan to ensure employees engage with the prediction market.

3. Employee Motivation

In terms of motivating an employee to participate in the corporate prediction market, we focus on two type of motivating factors – intrinsic and extrinsic. Intrinsic motivation comes from within the employee. It arises from a psychological need and results in employees acting “out of interest, ‘for the fun of it,’ and for the sense of challenge the activity at hand provides” (Reeve, 2014). Extrinsic motivation is supplied by environmental incentives and often follows a “do X in order to get Y” or “do X in order to avoid Z” type reasoning (Reeve, 2014). For
example, markets require a participant *purchase shares they believe profitable* in order to *increase the value of their portfolio* where the increased value of the portfolio may translate into further reward.

Oftentimes knowledge sharing is an additional request placed on employees outside their required job function (Pee & Lee, 2015). Firms have the ability to offer extrinsic rewards (or punishments) to encourage employees to undertake the additional tasks. Rewards can include financial incentives such as bonuses, material goods such as prizes, or intangible benefits such as praise and recognition (Bartol & Srivastava, 2002). Gerhart and Fang (2015) acknowledge that historically extrinsic motivation was seen as weaker than intrinsic motivation, specifically in terms of sustainability. Said differently, while extrinsic rewards produced the desired effect at first, they were unable to sustain the behavior in the long run. Extrinsic rewards also carry the risk of the “crowding effect” or “the corruption effect of extrinsic reward,” which posits when a reward is offered for a task the individual may, in the long run, only perform the task in exchange for the reward – essentially the introduction of an extrinsic reward has crowded-out any intrinsic motivation previously present (Osterloh & Frey, 2000). CET suggests “tangible rewards made contingent on task performance do reliably undermine intrinsic motivation” (Ryan & Deci, 2000b). Gagné (2009) puts forth similar claims stating, “attempting to motivate helping behavior with the use of tangible rewards decreases such behaviors.”

Intrinsic motivation arises from within the individual, firms are not able to *create* this motivation (Ryan & Deci, 2000b). While there are two distinct schools of thought on intrinsic motivation – one which stems from operant theory and positions activities that are a reward in-and-of-themselves as intrinsically motivating; the other stems from learning theory and positions activities which satisfy and innate psychological need as intrinsically motivating – we follow
Ryan and Deci (2000a) in defining intrinsically motivating activities as those which satisfy a need for competence, autonomy or relatedness, but, like Ryan and Deci, acknowledge these needs are often addressed through activities which are inherently interesting. Furthermore, firms may enhance the intrinsic motivation associated with an activity through environmental conditions only if the task originally held some intrinsic interest or value to the employee (Ryan & Deci, 2000a). Firms can attempt to encourage employees to internalize goals by fostering a sense of autonomy, competence, and relatedness they fulfill (Ryan & Deci, 2000b). In the case of internalizing a goal, the employee is still working to receive some extrinsic benefits but has aligned the activity with other values they hold and their behavior is similar to intrinsically motivated activity (Ryan & Deci, 2000b).

Feelings of competence, or skill mastering, can be fostered through extrinsic rewards such as praise only when coupled with a feeling of autonomy (Ryan & Deci, 2000a). Positive feedback has been shown to enhance intrinsic motivation where criticism has been shown to diminish it (Ryan & Deci, 2000a). Said differently, the external motivator – feedback – can influence intrinsic motivation in the same way it can influence a sense of competency. Researchers have historically focused more on understanding the effect of autonomy versus control on intrinsic motivation (Ryan & Deci, 2000a). In this case, autonomy refers to an internal locus of causality, or actions that are believed to be self-selected (Deci & Ryan, 1985).

Intrinsic rewards help address the multiple task problem, where explicit contracts or guidance cannot cover all expectations of the employee (Osterloh & Frey, 2000). When coupled with the issue of ‘free-loading’ – non-contributors benefiting from others’ contributions – intrinsic motivation is the only successful way to generate knowledge sharing as extrinsic motivators no longer work (Osterloh & Frey, 2000). This is not to say intrinsic motivation is
perfect. Since intrinsic motivations deal with achieving some level of internal (personal) satisfaction, emotions like jealousy and vengeance are no less motivating than feelings of altruism or love (Osterloh & Frey, 2000).

Ryan and Deci (2000b) proposed a continuum of motivation spanning from amotivation (a lack of action or just going through the motion) to intrinsic motivation (satisfaction comes from the activity itself). Extrinsic motivation lays between the two and is further segmented into four sub-categories (Ryan & Deci, 2000b). Figure One, taken from Ryan and Deci (2000b), illustrates the spectrum they describe.

**FIGURE ONE** (Emphasis added to Identified and Integrated Regulation)
While we acknowledge there may be some participants who remain amotivated and never engage, we suggest, in the subsequent section, focusing on creating an environment where as many participants as possible reach a level of *identified regulation* or *integrated regulation* which is as close to intrinsic motivation as extrinsic motivation can get. In fact, identified and integrated regulations have been combined with intrinsic motivation to form an autonomous motivation composite (Ryan & Deci, 2000b). Extrinsic motivation is needed when the task is not of inherent interest, and some other motivation is required to generate action. When presented with opportunities to increase a sense of relatedness to others, increase perceived competency, and increased autonomy it is expected individuals will better internalize and integrate the activity (RYAN DECI B).

Prediction markets may hold some inherent interest to employees. Firms can play to one of two themes when trying to attract employees. First, there may be a level of enjoyment for some employees, particularly those who enjoy the game-like elements, similar to stock trading or sports-betting. Second, employees may be attracted to the tool a mechanism for sharing their opinions. In either case, firms will need to structure the incentives carefully. In the next section, we review examples of prediction market incentives and how they may fit with a program designed to promote internal motivation.

4. Framework Development

Prediction markets offer a few unique advantages in regards to information sharing. First, employees are not required to codify their knowledge into composed texts (Pee & Lee, 2015), and thus participation requires a fraction of the time. Second, since the only piece of information shared is an opinion (essentially yes or no) on a clearly defined and constrained question there is less risk of losing knowledge power (Pee & Lee, 2015). Employees are not
required to share everything they know; they only have to share the final opinion on a specific question and are able to, in some sense, keep private all the details of the information used to reach that opinion. Finally, in certain contexts, prediction markets have outperformed other knowledge collecting methods, such as expert opinion, in generating predictions (Green, Armstrong, & Graefe, 2007).

Buckley (2016) lays out a case for prediction markets compared to other information aggregation mechanisms. First, prediction markets “incentivize the revelation of truthful information” (Buckley, 2016). It is thought the extrinsic incentive offsets factors such as emotional or professional concerns which might limit the sharing of truthful opinions (Buckley, 2016). Trading in the market eliminates some of the adverse outcomes associated with public knowledge sharing with regards to power relationships and social interactions (Buckley, 2016). Finally, the market includes a method for aggregating information (the pricing mechanism) and weights opinions according to their strengths (Berg & Rietz, 2006).

When viewed in comparison to other information aggregation methods (e.g., polls), the extrinsic motivators associated with prediction markets appear to be a strength. However, it is fairly clear in the management literature that intrinsic motivation results in better participation when the task is pro-social like knowledge sharing. It is worth noting upfront that the markets, simply by their nature, will always maintain some degree of extrinsic motivational factors, specifically because the units used to facilitate trade (points, currency) can be accumulated and lost. The question then becomes not which – intrinsic or extrinsic – motivation should be used, but rather how the two can be used in conjunction to best attract and retain participants.

Since the markets will never be without some extrinsic motivators, however trivial they may seem, we hesitate to say firms could rely solely on intrinsic motivation to garner
participation. It is impossible, in the presence of the inherent extrinsic motivation, to separate the impact of intrinsic and extrinsic motivators on participation. We, therefore, suggest firms focus on increasing participants’ sense of relatedness (form a community), competency (provide positive feedback) and autonomy (self-select into markets) to shift the motivation from an external “if this then that” mentality to an internalized desire to participate.

As pointed out earlier, to the extent prediction markets are viewed as being information sharing systems, intrinsic motivation plays a key role in the participation and retention of traders. Intrinsic motivation best thrives in a context where individuals feel they are competent, related to others, and in control (Reeve & Deci, 1996). Prediction markets, which stem from more traditional and general economic markets, leverage extrinsic motivators. Their strength is partially derived from the fact traders must “put their money where their mouth is” when forecasting future outcomes. It is impossible to remove ALL extrinsic motivators from the markets since they will always require a mechanism for trade and this unit of trade (currency) essentially functions as point system where participants are aware of changes in their total holdings. Additionally, good performance results in an increased balance (reward) while poor performance results in a decreased balance (punishment). It, therefore, makes sense to focus not on eliminating extrinsic motivators but rather to leverage the extrinsic motivators available to best foster and enhance a sense of intrinsic motivation. At a minimum, the extrinsic motivators should not be such that they diminish intrinsic motivation. Finally, since not everyone is inherently attracted to the same activities, for those not intrinsically motivated to participate, firms should attempt to have the employees internalize the goals of the market to better drive participation.
The market encourages knowledge-based trading by linking the incentives with performance. The simplest way to achieve this incentive alignment is through the use of monetary incentives (Buckley, 2016). That is not to say the markets must utilize real money, rather they can function with virtual currency so long as the more virtual currency accumulated in the market the more value it represents in the ‘real-world’ (Buckley, 2016). For example, the virtual currency could convert to real-money, at any given exchange rate; or the virtual currency could be exchanged for various material items of differing value. Ho and Chen (2007) recommend a compensation of $500 for participation although it is unclear how they determined this value. Interestingly, $500 is the maximum value a trader can invest in the IEM (Malone, 2004) and appears significantly higher than what firms are reportedly spending on internal markets. Cowgill and Zitzewitz (2015) report rewards valued at roughly $25-$100 per Google trader and “several $100 gift certificates” at Ford. The Hewlett-Packard markets gave participants roughly $50 for trading (Kiviat, 2004). The challenge with financial rewards is finding the correct balance between sufficiently motivating participation and not encouraging manipulation or other maladaptive behaviors (Buckley, 2016).

Prediction markets present a unique challenge, where traders may be able to influence the outcome of interest. The failed Defense Advanced Research Project Agency (DARPA) markets are a prime example of the concern associated with markets where traders could influence the outcome. See R. Hanson (2005); R. D. Hanson (2006); Looney (2004); Polk, Hanson, Ledyard, and Ishikida (2003) for detailed discussions of the DARPA markets and its criticisms. One method for limiting the perverse incentives is to limit the amount of money at stake for an individual trader (R. D. Hanson, 2006). PredictIt, a public real-money market focused on
politics, only allows traders to have $850USD associated with any one contract. Rather than simply pay for performance, through cash or a conversion of virtual currency to cash, Google linearly converted market currency to lottery tickets for a raffle where the prize budget was approximately $10,000 (Cowgill & Zitzewitz, 2015). All participants had a chance to win the lottery, but a strong performance in the market increased one’s likelihood of winning.

We take the position the market should not leverage cash incentives either in the form of real-money trading or in the conversion of virtual currency to real money at the close of the market. First, given the diminishing value of a dollar and the relatively small dollar values associated with the market's budget, cash appears to be a weak incentive. Consider the average Google programmer (according to Cowgill et al. (2009) participants in the market were more likely to be programmers) is paid over $80,000\(^3\) a reward of $100 represents less than 0.2% of their annual income. Prizes worth the equivalent of $100 or so may also not present strong incentives. That said, Gupta and Shaw (1998) report that management can use financial investments as a way to signal to employees what is important to management, so we encourage the use of a material reward or prize, just not cash. Particularly appealing is the linear conversion of trading currency to lottery tickets for prizes. While it is not explicitly stated how the lottery-ticket and prizes are managed, it seems allowing participants to allocate their tickets into the drawing for prizes of the greatest personal interest may enhance this incentive.

Siegel (2009) recommended against rewards based solely on becoming one of the top X traders because it removes the incentive for other traders if (or rather, once) the top performer have established a significantly large lead. Following from that, it seems to rely solely on a

\(^2\) https://www.predictit.org/About/HowItWorks
\(^3\) https://www.glassdoor.com/Salary/Google-Programmer-Salaries-E9079_D_KO7,17.htm
published leaderboard for reputational motivation would fail when traders realized securing a
position on the board was out of their grasp.

Google also “reset” the markets each quarter with employees starting out with equal
amounts of virtual currency (Cowgill & Zitzewitz, 2015). Not carrying over performance from
one ‘round’ of markets to the next may combat the risk of losing motivation as each player
would have a new opportunity to perform well and not need to ‘catch-up to’ a strong performer.
Conversely, it may weaken the incentive for top traders since they are essentially ‘reset’ each
time. Siegel (2009) recommends continually introducing new markets as a method of increasing
‘stickiness’ with participants and demonstrating the marketplace, overall, is active. It appears
unclear whether markets should be launched at set intervals (e.g., new sets of markets launch at
the start of each quarter) or if markets should be launched ‘randomly’ when the topic arises or if
it makes a significant difference at all. Along the same lines, it is unclear if it is preferable to
have the markets close at the same time (e.g., all close at the end of the quarter) or if markets can
close at varying times. If a firm wants to ‘reset’ markets quarterly, like Google (Cowgill &
Zitzewitz, 2015) having markets open and close at set intervals better facilitates this; however, if
firms ‘reset’ markets biannually or annually, than having markets open/close in an ad-hoc
fashion seems feasible. When markets are reset each quarter, or at some regular interval, it
removes the disincentive associated with a top spot being out of reach. It retains the incentives
associated with a top spot but allows people to have multiple (at each reset) chances at it.
Additionally, securing the top spot in one period may encourage the trader to try to ‘reclaim’ the
top spot in subsequent periods as a form of reputational incentive in addition to any prizes won.

Other firms have skipped the monetary incentives all together in exchange for
reputational rewards such as publicizing the best performing traders (Cowgill & Zitzewitz,
Buckley (2016) also suggests reputation and entertainment value as alternative motivators which could be used when incentivizing participants. Google dedicated 30% of its markets to “fun” topics – those of interest to employees but a clear relation to the business – and concluded the existence of fun markets may create liquidity in the serious markets (Cowgill et al., 2009). Markets regarding topics where there is a considerable ambiguous public information have better motivated trade compared to markets where a few insiders hold a large information advantage, regardless of how inherently interesting the topic is (Leigh & Wolfers, 2007). Atanasov et al. (2016) found leaderboards did not distort pricing (over- or under-confident estimates) which suggests the use of reputational incentives does not negatively impact market performance. By providing positive feedback to the top-performers, firms may be able to foster a sense of competency. As discussed earlier, negative feedback reduces intrinsic motivation, so we suggest not publishing all traders, but only the top N.

Firms must also be cognizant of the issues surrounding competition. The markets can easily be treated as a competition when those performing well are viewed as ‘winners’ profiting off the ‘losers’ not fairing as well. We use the term “losers” loosely here as often times the corporate prediction markets are fully subsidized by the firm and traders do not risk any of their personal wealth by participating. Researchers have found evidence of competition fostering as well as diminishing intrinsic motivation (Reeve & Deci, 1996).

Ho and Chen (2007) suggest senior management should encourage participation and clearly articulate the importance of the markets in decision making. Siegel (2009) echoed this idea as well as the importance of a “pre-launch campaign” to drive up interest and educate participants. Senior members of the firm could also take on a role of “champion” essentially becoming the face of the market and leading by the example of participating regularly (Siegel,
2009). The use of senior management to drive participation may put intrinsic motivation at risk if it is seen as trying to control behavior (Reeve, 2014). In other words, if management positions the market as something employees *should* engage with rather than using their communication to inform employees of the market as something they *could choose* to participate in (Reeve, 2014). The use of senior management may help an employee internalize the act of trading when trading is viewed as valued by people the employee respects or feels attached to (Ryan & Deci, 2000a). The prediction market creates an environment of relatedness, in that traders are connected to each other and engaging in a common activity.

In regards to continued participation, Ho and Chen (2007) suggest withholding earnings for traders not meeting some minimum threshold of activity. While we see how the threshold requirements could encourage traders, we generally shy away from this method until further research can demonstrate it would not adversely affect market pricing. If traders are forced to make trades regardless of a change in opinion the market pricing is expected to become noisier as the signals are not based on new information but rather required activity. Additionally, punishment can produce a number of negative side-effects including a damaged relationship between punisher (the firm) and the punishee (the trader) and has been shown to be an ineffective method of motivation (Reeve, 2014). It may prove more successful to encourage continued engagement in the markets by striving to foster an intrinsic enjoyment and internalized acceptance of the goals rather than punish those for not joining the market. Management can also acknowledge or reward participants simply for participating. For example, similar to the lottery tickets provided by Google. Rewards which are unexpected have not been shown to reduce intrinsic motivation (Reeve, 2014).

**Conclusion**
We have leveraged intrinsic and extrinsic motivational research and the lens of cognitive evaluation theory to examine and propose methods of attracting and retaining participants for internal prediction markets. It is unclear, and worthy of exploration, if this work could be generalized and leveraged to attract and retain participants in larger, public markets such as the Iowa Electronic Market\(^4\) or PredictIt\(^5\). Our paper is limited by one major assumption which was implicit in the design of incentives. Specifically, we have assumed employees would view a Corporate Prediction Market as a method of knowledge sharing and thus we have assumed the research done with regard to the impact of intrinsic and extrinsic motivation on knowledge-sharing is applicable. Maciejovsky and Budescu (2013) demonstrated prediction markets could be used for knowledge sharing but it is not clear in the literature if this is how they are actually viewed by participants.

We were also limited by the relative lack of detailed publications discussing how corporate predictions are implemented in practice. While the incentive evaluation was informed by both generalized descriptions in published research and personal experiences it would have benefited from detailed case studies discussing the finer elements of corporate prediction market implementation and use.

By utilizing theory from organizational management we have shifted the conversation pertaining to prediction market participation from the practical to the academic, while also helping to inform practice. Prediction markets have received academic attention from the Economics field and but minimal attention from Management. This work is a beginning step towards understanding the phenomenon of corporate prediction markets from an organizational perspective. Empirical testing of the suggestions made here – both to confirm how traders view

\(^4\)http://tippie.biz.uiowa.edu/iem/
\(^5\)https://www.predictit.org/
prediction markets and how traders respond to various incentives would be a logical extension of the work. We contribute to the prediction market literature by addressing the issue of motivation to participate. We also contribute to the Cognitive Evaluation Theory literature by applying the theory to a new phenomenon.
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Active Learning: Enhancing the Outcomes of Virtual Pedagogies*

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Abstract

This paper initially defines an integrated model of “active” learning processes, and elaborates a Pedagogic Continuum to achieve active learning goals. Prior research is then categorized as traditional or virtual and represented using that Continuum. Subsequently, the result of a pre- / post- study of 200+ undergraduate business statistics students addresses learning outcomes of the specified pedagogies and demonstrates the impact of a supplemental engaged learning component. Overall, no performance differences between traditional and virtual pedagogies, measured on three dimensions, were found; however, the engaged learning component was associated with improved learning outcomes on each of those dimensions.

The Balance:

Improving student involvement in learning, under various names, has been a goal of teachers for decades, if not centuries or millennia. Both Aristotle’s *Nichomachean Ethics* and Socratic dialogue are examples of such pedagogies. More recently, Kolb (1984) proposed the Experiential Learning Model (ELM), shown at Figure #1, to integrate active learning processes. Kolb’s ELM is important because it is associated with different student learning styles (Diverger, Assimilator, Converger, and Accommodator). Those styles can be identified by a simple questionnaire and differ by student major (Loo, 2002). The ELM also involves active learning skills – analyzing, synthesizing, and evaluating – associated with the higher orders of Bloom’s Cognitive Taxonomy (Bloom et al., 1956). The ELM outcomes can be compared with those of pure academic learning, which consists of only passive constructive and reproductive learning.

Figure 1

The Experiential Learning Model

4. Concrete Experience
(Proactive learner involvement)

3. Active Experimentation
(Integration through problem solving skills)

2. Abstract Conceptualization
(Enhanced analytic skills to conceptualize experience)

1. Reflective Observation
(Reflection on the experience)

Accommodator
Converger
Assimilator
Diverger

* The author expresses his deep appreciation to Dr. Mary Malliaris, Chair of the Information Systems/ Supply Chain Management Department, and Dr. Faruk Guder, former Associate Dean, both of the Quinlan School of Business, Loyola University Chicago, for their encouragement and support of this project. Mr. James Fritz, the author’s research assistant, contributed notably to this paper.
activities. Active ELM activities are found to be more efficient than passive learning and result in improved learning outcomes (Stavenga de Jong et al., 2006).

The literature suggests four somewhat overlapping variations of active learning, including engaged learning, enhanced learning, experiential learning, and experimental learning. These four variations generally correspond to the four phases of the ELM.

Engaged learning refers to the degree of attention, interest, curiosity, or passion that students exhibit when they are learning, including the motivation to learn. Engaged learning allows students to directly examine, characterize, analyze, and evaluate the object of study so they can gain knowledge about it in an environment that is disassociated from the traditional classroom. This approach to learning has always been central to the sciences; laboratory and field exercises are examples of engaged learning (Bowen, 2014). As such, engaged learning emphasizes Phase 1 of the ELM, Reflective Observation.

Enhanced learning most often refers to an environment supported by a technologically-equipped classroom or other electronic facilitation, or, more generally, enhanced access and analytic skills. For example, enhanced learning has the potential to address issues of educational equity through greater access; correspondingly, it can reduce the cost of reaching an audience that may not otherwise have such educational opportunities (Danks, no date). Thus, enhanced learning facilitates and broadens Abstract Conceptualization, Phase 2 of the ELM. This type of learning then is differentiated through the medium by which it is implemented.

Experiential learning is a method of learning through experience and applying knowledge and conceptual understanding to real-world problems and situations. Students thus can take a more active role in their education. Experiential learning provides students with opportunities to develop skills and abilities necessary to succeed outside an educational environment; examples include internships and service learning. Internships often take the form of a credit-bearing, free-standing course that is not tied to a traditional course. Alternatively, service learning facilitates an optional or required out-of-classroom community service or volunteer project, and is attached to programs or other credit-bearing experiences (Experiential, no date; Coker, no date). Experiential learning roughly corresponds to Phase 3 of the ELM, Active Experimentation.

Finally, experimental learning is defined as learning through experimentation in an educational setting in which knowledge is applied in a real-world experimental setting. An effective experimental learning situation has been demonstrated in a Leadership Skills Development Module course at the Nicolaus Copernicus University in Poland (Kaliaska, 2010). The 10-week course was delivered using a mixture of lectures, role-playing games, exercises, and discussion. One of the conclusions of the study was that even though the module improved leadership skills in some participants, it was less effective with others. Though the impact of experimental learning has been well documented in numerous environments, the methods by which leadership skills are taught should be adjusted to fit the individual’s career aspirations or educational goals. Experimental learning then mirrors Phase 4 of the ELM, Concrete Experience.

Note that experiential learning is usually applied to circumstances outside of the traditional classroom, including service work or volunteer projects, while experimental learning is more often conducted in a traditional classroom setting, with lectures or other activities, which are directly focused toward the external environment. This distinction between experiential and experimental learning, then, is primarily one of venue.
This four-step process is notably overlapping and culminates in experimental learning, which, cumulatively, involves the principles of:

1. **Purposive** – relevance of the task to student concerns.
2. **Reflective** – reflection and research on the meaning of the learning.
3. **Negotiated** – definition of goals and leadership in self-development activities.
4. **Critical** – appreciation of different ways to learn the content.
5. **Complex** – use of interdisciplinary content to assess real-life situations.
6. **Situation-Driven** – integration of prior knowledge to enhance understanding.
7. **Engaged** – real life tasks are the basis for learning.

(Barnes 1989)

Phase 2, enhanced learning activities, can be integrated in any phase of the ELM – or not. Thus, these principles can involve either traditional face-to-face or virtual technology, including small group or class discussions, study groups or teams, various games or class problems, and learning by teaching or presenting. Of course, technology can facilitate the conduct, delivery, and capturing of any of these activities. This study then evaluates, on several dimensions, whether students perform equally in traditional or virtual environments (the Phase 2 Effect), and whether engaged learning (EL) activities improve outcomes (the Phase 1 Effect).

Distance education has also been pursued under various names (correspondence courses, online, virtual) and technologies for more than 100 years (Daymont & Blau, 2008); yet, it continues to be beset by a range of concerns among administrators, teachers, and students (Allen & Seaman, 2011-2016). Some 77% of public university administrators claim that online education is equal to or better than traditional classroom pedagogies and more than 65% state that online education is critical for their university’s long-term strategy. However, less than 30% of those administrators affirm that their faculty accept the value and legitimacy of online education, and less than 50% of the university strategic plans of those administrators contain online education initiatives (Allen & Seaman, 2016). This discrepancy may be explained because administrators likely see the revenue, program growth, and convenience of online programs, while faculty may balk due to concerns with workload or the quality of such programs.

This lack of consensus among academicians about traditional and virtual pedagogies mirrors a government meta-analysis of more than 1,000 studies between 1996 and 2008 (U.S. Department of Education, 2010). That review found no consistent outcome from K-12 to graduate environments and included different student backgrounds, numerous technologies, various experimental designs, and single and multiple instructors, courses, and time frames. In those studies, course activities were also notably different, possibly introducing externalities.

Though many tout important advantages of online programs, such as the convenience of anytime / anywhere asynchronous attendance and self-paced study, others find online programs to be a euphemism for “easier” classes (Daymont & Blau, 2008). Some studies confound student performance outcomes by addressing the nature of the program (Kakish, Pollacia, & Heinz, 2012), student course satisfaction or teacher “likeability” (Daymont & Blau, 2008), or faculty workload (Utts, Sommer, Acredolo, Maher, & Matthews, 2003). Additional concerns of distance education include insufficient hardware capacity to fully share video technologies, inability to securely administer examinations or to transfer online credits, and difficulties of achieving qualitative, conceptually-focused, or behaviorally-defined course objectives.
However, despite these concerns, demand for virtual programs continues to outpace supply (Daymont & Blau, 2008; Clinefelter & Aslanian, 2015). Demand for online programs increased annually by between 9.7% and 36.5% from 2003 to 2010, compared with increases of between 0.6% and 4.7% for traditional programs. At the same time, online enrollments grew from 12% to 31% of total enrollments. In 2014, more than 20 million students took at least one online course. This growth predominates in engineering and computer information systems, with lower growth rates in liberal arts and social sciences, suggesting that quantitative courses may be more amenable to virtual education than qualitative courses (Allen & Seaman, 2010 – 2016).

Given this background of distance education programs – and the myriad of factors, many of which may be somewhat exogenous, that contribute to student performance – this paper considers ways to balance the access, low cost, and convenience of online methods against the purported quality of more direct, “hot” (McLuhan, 1964) traditional instructor contact with the class. Further, the contribution of “hot” supplemental engaged learning activities is also evaluated. Specifically, this paper assesses the outcomes of six undergraduate business statistics sections taught by one instructor in two semesters, separately using traditional and virtual pedagogies, including one EL section, with otherwise very minimal differences of course activities. The impacts of Phase 1 and Phase 2 activities of the ELM are thus evaluated.

Research Background

This section initially defines a Continuum of five alternate pedagogies (adapted from Allen & Seaman, 2010 – 2016), then evaluates eight prior research efforts on that Continuum. The directness of instructor contact with the class is the basis for this Continuum. Though this model abstractly describes the “hotness” of pedagogic processes, individual faculty styles may vary considerably from class to class. The traditional pedagogy, defined as having regular and direct face-to-face instructor contact with the class (“hot” communication), may be better suited for undergraduate, qualitative, or behavioral courses, while less “hot” variations may be more appropriate for graduate, quantitative, or computational courses. This Continuum of Alternate Pedagogies is shown at Figure 2; the five pedagogic models are subsequently defined.

The eight articles referenced in Figure 2 and reviewed below represent the important undergraduate business-course studies that compare traditional with virtual pedagogies. Some of these studies describe courses as traditional, but appear to use some web-facilitated processes.

1) Brown & Liedholm (2002) report the outcomes of five sections of an undergraduate microeconomics course with 700+ students (two traditional, one hybrid, and two online sections). Performance was measured by a post-survey of 37 exam questions. In this early study, the researchers conclude that virtual students underperformed traditional students and that virtual pedagogies were “inferior” to live instruction. However, groups were taught by different instructors and used various learning supplements for online sections.

2) Daymont & Blau (2008) compare seven sections of an undergraduate management course: two asynchronous and five traditional sections with some web-based support. Those researchers found final grades (a subjective measure) were not different, but that average quiz scores, a more objective measure, were significantly different. Online students outperformed traditional students, which the researchers acknowledge may have been explained by the higher GPA, different majors, and more upper classmen and transfer students in the online sections.
Figure 2  
Continuum of Alternate Pedagogies

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<th>Directness and Immediacy of Instructor Personal Contact with the Class</th>
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<td>Traditional</td>
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<td>Traditional Face-to-Face</td>
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Reference

3) Friday, Friday-Stroud, Green, & Hill (2006) evaluate non-traditional undergraduate business students in eight semesters of both an organization and management course and a strategic management course (respectively, 593 and 754 students). The researchers found no significant differences in course grade based on traditional vs online delivery method. However, the authors acknowledge “major differences” in the pedagogies: traditional sections required student presentations, had guest speakers, and viewed topical videos, while online students were graded on written synopses of management articles.

4) Kakish et al. (2012) compare four sections (two hybrid and two traditional) of an undergraduate statistics course with a total of 92 students taught by one instructor at an open access (automatic admission for qualified students) undergraduate college. Though traditional groups performed slightly better than hybrid groups, no significant differences were found.

5) Keller, Hassell, Webber, & Johnson (2009) compare two sections of a managerial accounting course, one traditional and one hybrid, with a total of 235 students. They found that performance of the two sections was not significantly different when controlled for Scholastic Aptitude Test scores and for grades in a prior accounting class. In fact, reported $r^2$ values of the two groups were within 0.5% and most differences were explained by the control variables.

6) McCarty, Bennett, & Carter (2013) compare four sections (two online asynchronous and two traditional) of a principles of microeconomics course based on final course grades. They found
no significant differences in performance among sections. However, they did report that online students were significantly older and had significantly higher GPAs.

7) Ury (no date) compares online and traditional sections of undergraduate management information systems (MIS) and elementary programming (EP) courses. Three and four teachers were involved during five and four years, respectively, with 576 traditional and 112 online MIS students and 245 traditional and 74 online EP students. Based on administrative data, the researchers determined that there were no significant externalities that could influence group scores. The results, measured by final grades, showed that traditional students performed at significantly higher levels than online students.

8) Utts et al. (2003) compare a traditional section of 208 elementary statistics students with a hybrid section of 77 students. The courses met at the same time and used the same text, but the hybrid section met for one hour 20 minutes/week, while the traditional section met for two hours 30 minutes/week. Exams were also different; however, based on 12 multiple choice questions given in a pre- / post- design, no significant differences were found.

These studies generally found no difference in group performance outcomes; however, where encountered, those differences may have been notably perturbed by externalities. For example, use of course grade, as a dependent variable, may evaluate compliance or effort, rather than learning, and may be based on some subjective input (Friday et al., 2006). Further, some studies used multiple instructors and time frames (Friday et al., 2006; Ury, no date), different learning support activities (Brown & Liedholm, 2002), different evaluation methods (Friday et al., 2006; Daymont & Blau, 2008), varying student attributes, including effort, backgrounds, and majors (Brown & Liedholm, 2002; Damianov, Kupczynski, Calafiore, Damianova, Soydemir, & Gonzalez, 2009), class and age (Daymont & Blau, 2008; McGlone, 2011), and degree program (Friday et al., 2006). Additionally, different research objectives were considered, including evaluation of the instructor, student course satisfaction, and instructor workload (Utts et al., 2003), student withdrawal rates (Wilson & Allen, 2013), and traditional vs non-traditional student programs (Friday et al., 2006). The factors most consistently found to be significant moderators in these studies were GPA (Keller et al., 2009; Damianov et al., 2009; McCarty et al., 2013), gender (Friday et al., 2006; Daymont & Blau, 2008; McCarty et al., 2013), and class and age (Daymont & Blau, 2008; McGlone, 2011).


Research Design and Hypotheses

During the spring and fall semesters, 2015, the author taught six sections of an undergraduate business statistics course: one EL section, two web-facilitated (WF) sections, and three voluntary virtual hybrid (VVH) sections. As a university core course, business statistics is taken primarily by business majors (≈ 85%), but is open to majors from all colleges. Most students
were either Frosh or Sophomores and twenty years old or less. The thirteen course topics include definitions, charts, and graphs, measures of centrality and variation, binomial and Poisson distributions, confidence intervals, one- and two-population hypothesis tests, correlation, ANOVA, and simple and multiple regression. Sections used the same syllabus (with meeting time differences) and text, received the same PowerPoint lectures, did the same homework problems, and had access to the same supplemental materials (practice problems and tests) and extra credit.

The sections varied in that VVH students could choose to attend synchronously by connecting to an Adobe Connect site with audio interaction. Nearly all VVH students attended some classes virtually, and some 45 – 50% of each session attended virtually. VVH sessions were archived and automatically available to VVH students and on-request to students of the other sections (there were two such requests). Alternatively, the EL section required a case study of a corporate database with 60,000+ observations and a briefing of corporate executives, instead of the textbook case database of 105 observations. Attendance was taken at most meetings of all sections; however, exam preparation meetings and exams, and the first several sessions, required in-person attendance for all sections.

The EL section satisfies a university Engaged Learning/Service Learning program requirement. Students in this section interviewed the Director of the Homelessness Prevention Call Center (HPCC), a component of the Catholic Charities of Chicago, and worked with the HPCC database. Homeless rates in Chicago are among the highest nationally, and extreme temperatures (both heat and cold) exacerbate risks for homeless. The HPCC facilitates funding opportunities for those facing homelessness. The database consists of six separate Excel files which identify client demographics, the staff member taking the call, the reasons for the need (lost job, etc.), the outcome of the call, and amounts and sources of funding provided. Students visited the HPCC facilities and evaluated several management decisions pertaining to cost management, system efficiency, and equity of service, using multiple algorithms (correlation, hypothesis testing, ANOVA, multiple regression). The diagnosis was briefed to HPCC staff at the end of the semester. As such, these activities achieve all of the principles of Experiential Learning (Barnes, 1989). The understanding and support of the HPCC mission are purposive, reflective, negotiated, and critical; while the database itself is a complex, situation-driven, and engaging activity. Further, these activities, though primarily engaged learning, are also components of the other ELM Phases.

The three sections per semester were managed with one course website, permitting the instructor to easily update and clarify the material. Further, some 15 student questions a week (often about cases, homework, and exams) were received by email from individual students, and the response was “burst” to all sections. Here, traditional (EL and WF) sections, position #2 on the Pedagogic Continuum, are compared with the virtual (VVH) sections, position #3, and the EL section is compared with the non-EL sections.

A pre- / post- survey of 26 multiple choice questions and eight demographics, shown at Appendix 1, was approved by the University Institutional Review Board (IRB) and given to all sections during the second and next-to-last course meetings. The surveys contained the same questions, but the responses were presented in varying sequences. There were 13 conceptual or definitional questions, and 13 quantitative or computational questions, one each for the thirteen weekly topics and thirteen assigned chapters of the course text. Consistent with IRB guidance,
Based on the above-defined pedagogic processes and research, it is hypothesized that:

Hₐ₁ – Null: there is no performance improvement difference between traditional (EL and WF) and virtual (VVH) sections.

Hₐ₂ – Null: there is no performance improvement difference between the EL section and the non-EL sections in the aggregate.

Hₐ₃ – Null: there is no difference of responses to basic materials (which some students cover in prior courses) and more advanced topics between traditional (EL and WF) and virtual (VVH) sections.

Hₐ₄ – Null: there is no difference of responses to basic materials (which some students cover in prior courses) and more advanced topics between EL section and the non-EL sections in the aggregate.

Hₐ₅ – Null: there is no difference of responses to qualitative and quantitative topics between traditional (EL and WF) and virtual (VVH) sections.

Hₐ₆ – Null: there is no difference of responses to qualitative and quantitative topics between the EL section and the non-EL sections in the aggregate.

The Findings

During the spring semester, 2015, 116 students participated in the “before” survey and 104 students in the “after” survey. During the fall semester, 2015, 133 students participated in the “before” survey and 109 students in the “after” survey. The differences of 12 students, 10.3%, in the spring semester, and 24 students, 18.0%, in the fall semester, represent drop and absence rates. Table 1 shows the number and proportion of student demographics for the EL, WF, and VVH sections and the group total, each with Z scores. Note that sample terminology – n, X-bar, and s – is used here (considering the student absences and drops); however, the observations otherwise represent course section populations. The Z test of one proportion samples is used to compare each section against the total and thus test if externalities were introduced through student course-section selection. The formula for the Z test of one proportion samples is:

\[ Z = \frac{p - \pi}{\sqrt{\pi(1-\pi)/n}} \]

where p = sample proportion; \( \pi = \) population proportion; n = sample size

Formula #1

Table 1 shows marginal statistical significance for Business Majors (\( Z = -1.85; p_{\text{two tail}} = .064 \)) and some significance for Age (\( Z = -1.592, p_{\text{two tail}} = .112 \)) and Class (\( Z = -1.317, p_{\text{two tail}} = .186 \)). With these exceptions, selection externalities were minimal. In the EL section, business majors were marginally underrepresented and older, upper-class students were slightly overrepresented. The impact of these marginal externalities is subsequently considered.
## Table 1

Demographic Variables - After Responses

<table>
<thead>
<tr>
<th>Gender</th>
<th>Male</th>
<th>Female</th>
<th>Total</th>
<th>Z**</th>
</tr>
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<tbody>
<tr>
<td>EL Section (1)</td>
<td>9</td>
<td>.450</td>
<td>11</td>
<td>.550</td>
</tr>
<tr>
<td>WF Sections (2)</td>
<td>49</td>
<td>.538</td>
<td>42</td>
<td>.462</td>
</tr>
<tr>
<td>VVH Sections (3)</td>
<td>63</td>
<td>.534</td>
<td>55</td>
<td>.466</td>
</tr>
<tr>
<td>Total All Sections (6)</td>
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<td>.528</td>
<td>108</td>
<td>.472</td>
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<table>
<thead>
<tr>
<th>Age</th>
<th>≤20</th>
<th>&gt; 20</th>
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<tr>
<td>EL Section (1)</td>
<td>15</td>
<td>.714</td>
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<td>WF Sections (2)</td>
<td>75</td>
<td>.842</td>
</tr>
<tr>
<td>VVH Sections (3)</td>
<td>103</td>
<td>.797</td>
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<td>Total All Sections (6)</td>
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<table>
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<tr>
<th>Class</th>
<th>Frosh &amp; Sophomores</th>
<th>Juniors &amp; Seniors</th>
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<td>EL Section (1)</td>
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<td>WF Sections (2)</td>
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<td>.738</td>
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<td>VVH Sections (3)</td>
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<td>.797</td>
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<td>Total All Sections (6)</td>
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<td>.760</td>
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<table>
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</thead>
<tbody>
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<td>.500</td>
</tr>
<tr>
<td>WF Sections (2)</td>
<td>41</td>
<td>.456</td>
</tr>
<tr>
<td>VVH Sections (3)</td>
<td>53</td>
<td>.450</td>
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<td>Total All Sections (6)</td>
<td>105</td>
<td>.457</td>
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</table>

<table>
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<tr>
<th>Location of Living</th>
<th>Home or Apt</th>
<th>On Campus</th>
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</thead>
<tbody>
<tr>
<td>EL Section (1)</td>
<td>9</td>
<td>.450</td>
</tr>
<tr>
<td>WF Sections (2)</td>
<td>27</td>
<td>.328</td>
</tr>
<tr>
<td>VVH Sections (3)</td>
<td>41</td>
<td>.347</td>
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<td>Total All Sections (6)</td>
<td>77</td>
<td>.345</td>
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<table>
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<tr>
<th>Prior Statistics Experience</th>
<th>Yes</th>
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<td>EL Section (1)</td>
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<td>.250</td>
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<td>WF Sections (2)</td>
<td>12</td>
<td>.141</td>
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<tr>
<td>VVH Sections (3)</td>
<td>24</td>
<td>.203</td>
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<td>Total All Sections (6)</td>
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<td>.184</td>
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<table>
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<th>Other</th>
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<td>15</td>
<td>.750</td>
</tr>
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<td>WF Sections (2)</td>
<td>79</td>
<td>.940</td>
</tr>
<tr>
<td>VVH Sections (3)</td>
<td>102</td>
<td>.864</td>
</tr>
<tr>
<td>Total All Sections (6)</td>
<td>196</td>
<td>.883</td>
</tr>
</tbody>
</table>

* Minor variations in n values resulted from incomplete survey responses
** p values shown for p < .200
Table 2 shows average correct responses, improvements, and standard deviations ($X_{1\text{-bar}}, X_{2\text{-bar}}, X_{3\text{-bar}}, s_1, s_2$) of “before” and “after” surveys for the EL, WF, and VVH sections, and totals of traditional sections, of non-EL sections, and of all sections. The improvement from $X_{1\text{-bar}}$ to $X_{2\text{-bar}}$ is shown as $X_{3\text{-bar}}$. The $Z$ test of group means, Formula #2, is used to evaluate performance improvement differences of each group.

$$Z = \frac{(X_{1\text{-bar}} - X_{2\text{-bar}})}{\sqrt{\frac{s_1^2}{n_1} + \frac{s_2^2}{n_2}}}$$  \hspace{1cm} \text{Formula #2}

Table 2
“Before” and “After” Correct Responses and Improvement Values

<table>
<thead>
<tr>
<th></th>
<th>“Before”</th>
<th>“After”</th>
<th>Improvement</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$n$ $X_{1\text{-bar}}$ $s_1$</td>
<td>$n$ $X_{2\text{-bar}}$ $s_2$</td>
<td>$X_{3\text{-bar}}$ $Z$</td>
</tr>
<tr>
<td>EL Section (1)</td>
<td>23 8.48 2.45</td>
<td>20 12.99 3.69</td>
<td>4.51 5.71*</td>
</tr>
<tr>
<td>WF Sections (2)</td>
<td>96 9.03 2.13</td>
<td>83 12.71 3.35</td>
<td>3.68 8.61</td>
</tr>
<tr>
<td>VVH Sections (3)</td>
<td>130 9.51 2.35</td>
<td>110 12.45 2.05</td>
<td>3.34 12.22</td>
</tr>
<tr>
<td>Total – EL &amp; WF Sections (3)</td>
<td>119 8.91 2.26</td>
<td>103 12.76 3.42</td>
<td>3.80 9.61</td>
</tr>
<tr>
<td>Total – Non-EL Sections (5)</td>
<td>226 9.30 2.21</td>
<td>193 12.56 2.51</td>
<td>3.26 13.99</td>
</tr>
<tr>
<td>Total – All Sections (6)</td>
<td>249 9.23 2.32</td>
<td>213 12.60 3.03</td>
<td>3.37 13.24</td>
</tr>
</tbody>
</table>

* The one-tailed t test critical value with 19 degrees of freedom and an error of .0005 is 3.883

The total test for all sections found $Z = 13.24$ ($p < .001$). Subgroup means and $Z$ scores are also given. The $Z$ test for the EL section, though significant, is notably less than for other sections because of the smaller sample size. These scores find virtually no probability that “before” and “after” scores of either the total groups or subgroups were the same, suggesting, as expected, that significant learning occurred throughout. Though each subgroup is treated as a population, if the number of observations is less than 30, the more conservative t test (footnoted) may better represent the outcomes.

Considering $H_{01}$, based on the Formula #2 $Z$ test, the average improvement between traditional (EL and WF) and virtual (VVH) sections, which is 3.80 minus 3.34 = .46, does not differ significantly ($Z = 1.24$; $p_{\text{two tail}} = .21$). This evaluation fails to reject $H_{01}$; there is not a performance improvement difference between the traditional and virtual sections – the traditional sections show greater, but not significantly greater, improvement.

Considering $H_{02}$, based on the Formula #2 $Z$ test, the average improvement between the EL section and the non-EL sections, which is 4.51 minus 3.26 = 1.25, differs significantly ($Z = 2.002$, $p_{\text{two tail}} < .05$); the EL section improved more than the non-EL sections in the aggregate. However, the EL section “before” results were somewhat lower than those of the other sections. This EL-section outcome, though significant, may have resulted in part because non-business majors, who needed an EL course, did not initially understand the business context of some questions.
Table 3 shows average correct responses, decreases, and standard deviations ($X_{1}$-bar, $X_{2}$-bar, $X_{3}$-bar, $s_{1}$, $s_{2}$) of first and third cycle responses using the “after” results for the EL, WF and VVH sections, and totals of traditional sections, of non-EL sections, and of all sections. The decrease in correct responses from $X_{1}$-bar to $X_{2}$-bar is shown as $X_{3}$-bar and is expected with more advanced material. The $Z$ test of group means, Formula #2, is used to evaluate performance decreases between the easier first and more difficult third cycles among various groups.

Table 3

1st Cycle and 3rd Cycle Responses Using “After” Results

<table>
<thead>
<tr>
<th></th>
<th>1st Cycle</th>
<th>3rd Cycle</th>
<th>Decrease</th>
</tr>
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<tbody>
<tr>
<td></td>
<td>n</td>
<td>$X_{1}$-bar</td>
<td>$s_{1}$</td>
</tr>
<tr>
<td>EL Section (1)</td>
<td>20</td>
<td>5.10</td>
<td>1.20</td>
</tr>
<tr>
<td>WF Sections (2)</td>
<td>83</td>
<td>5.10</td>
<td>1.58</td>
</tr>
<tr>
<td>VVH Sections (3)</td>
<td>110</td>
<td>4.84</td>
<td>1.32</td>
</tr>
<tr>
<td>Total – Traditional Sections (3)</td>
<td>103</td>
<td>5.12</td>
<td>1.44</td>
</tr>
<tr>
<td>Total – Non-EL Sections (5)</td>
<td>193</td>
<td>4.95</td>
<td>1.46</td>
</tr>
<tr>
<td>Total – All Sections (6)</td>
<td>213</td>
<td>4.97</td>
<td>1.30</td>
</tr>
</tbody>
</table>

* The one-tailed test critical value with 19 degrees of freedom and an error of .0005 is equal to 3.883

The total test found $Z = 18.95$ ($p < .001$) for all sections. Subgroup mean decreases and $Z$ scores are also given. The $Z$ test for the EL section, though significant, is notably less than that for other sections due to the smaller sample size. These scores show virtually no probability that first and third cycle performance of either the total groups or subgroups were the same, suggesting, as expected, that a significant decrease in performance occurred throughout as course topics became more difficult. Though each subgroup is treated as a population, however, if the number of observations is less than 30, the more conservative $t$ test may better represent the outcomes.

$H_{03}$, that there is no difference in response to basic materials (which some students may have covered in prior courses) and more advanced topics between traditional (EL and WF) and virtual (VVH) sections, is addressed by the $Z$ test, Formula #2. That test found a difference between $X_{3}$-Total Traditional-bar and $X_{3}$-VVH-bar of 2.29 minus 2.35 = -0.06 ($Z = .34; p_{two\,tail} = .73$). This evaluation fails to reject $H_{03}$; there is no difference between the traditional and virtual sections in response to basic and more advanced materials.

$H_{04}$, that there is no difference in response to basic materials (which some students cover in prior courses) and more advanced topics between the EL section and the non-EL sections, is addressed by the $Z$ test, Formula #2. That test found a difference between $X_{3}$-EL-bar and $X_{3}$-Total Non-EL-bar of 1.85 minus 2.39 = -0.54 ($Z = -1.76; p = 7.8\%$). This evaluation marginally rejects $H_{04}$; there is a likely difference in response as the course progressed from basic to more advanced materials between the EL and Non-EL sections – the EL section performance decreased at a marginally significant lesser rate than the non-EL sections.

Table 4 shows average correct responses, differences, and standard deviations ($X_{1}$-bar, $X_{2}$-bar, $X_{3}$-bar, $s_{1}$, $s_{2}$) of qualitative and quantitative responses using the “after” results for the EL, WF and VVH sections, and totals of traditional sections, of non-EL sections, and of all sections.
The difference in correct responses from $X_1$-bar to $X_2$-bar is shown as $X_3$-bar, which is expected, given the non-quantitative nature of the program. A Z test of group means, Formula #2, evaluates differences between the qualitative and quantitative responses among various sections.

Table 4
Qualitative and Quantitative Responses Using “After” Results

<table>
<thead>
<tr>
<th></th>
<th>Qualitative</th>
<th></th>
<th>Quantitative</th>
<th></th>
<th>Difference</th>
<th></th>
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<tr>
<td></td>
<td>n</td>
<td>$X_1$-bar</td>
<td>$s_1$</td>
<td>$X_2$-bar</td>
<td>$s_2$</td>
<td>$X_3$-bar</td>
</tr>
<tr>
<td>EL Section (1)</td>
<td>20</td>
<td>7.17</td>
<td>2.05</td>
<td>5.79</td>
<td>1.54</td>
<td>1.32</td>
</tr>
<tr>
<td>WF Sections (2)</td>
<td>83</td>
<td>7.28</td>
<td>2.04</td>
<td>5.50</td>
<td>2.02</td>
<td>1.78</td>
</tr>
<tr>
<td>VVH Sections (3)</td>
<td>110</td>
<td>6.89</td>
<td>1.96</td>
<td>5.01</td>
<td>1.68</td>
<td>1.88</td>
</tr>
<tr>
<td>Total Traditional Sections (3)</td>
<td>103</td>
<td>7.26</td>
<td>2.04</td>
<td>5.56</td>
<td>2.13</td>
<td>1.70</td>
</tr>
<tr>
<td>Total Non-EL Sections (5)</td>
<td>193</td>
<td>7.16</td>
<td>2.00</td>
<td>5.19</td>
<td>1.83</td>
<td>1.94</td>
</tr>
<tr>
<td>Total - All Sections (6)</td>
<td>213</td>
<td>7.06</td>
<td>1.78</td>
<td>5.47</td>
<td>1.97</td>
<td>1.59</td>
</tr>
</tbody>
</table>

* The one-tailed t test critical value with 19 degrees of freedom and an error of .025 is equal to 2.093

The total test for all sections found $Z = 8.74$ ($p < .001$). Subgroup means and Z scores are also given. The Z test for the EL section, though significant, is notably less than for other sections because of the smaller sample size. These scores find virtually no probability that qualitative and quantitative scores of either the total groups or subgroups were the same, suggesting, as expected, a significant difference in learning qualitative and quantitative skills throughout. Though each subgroup is treated as a population, if the number of observations is less than 30, the more conservative t test (footnoted) may better represent the outcomes.

$H_{05}$, that there is no difference in response to qualitative and quantitative questions between traditional (EL and WF) and virtual (VVH) sections, is addressed by the Formula #2 Z test. That test found a difference between $X_3$-Total Traditional-bar and $X_3$-VVH-bar of 1.70 minus 1.88 or -0.18 ($Z = .68$; $p$ two tail $= 50.3$%). This evaluation fails to reject $H_{05}$; there is no difference in responses to qualitative and quantitative questions between traditional and virtual sections.

$H_{06}$, that there is no difference in response to qualitative and quantitative questions between the EL section and the Non-EL sections, is addressed by the Formula #2 Z test. That test found a difference between $X_3$-EL-bar and $X_3$-Non-EL-bar of 1.32 minus 0.62 ($Z = -1.68$; $p$ two tail $= .093$). This evaluation marginally rejects $H_{06}$; there is a likely difference regarding response to qualitative and quantitative questions between the EL and Non-EL sections – the EL section performance decreased at a marginally significant lesser rate than the non-EL sections.

Discussion and Conclusions

This study used Kolb’s ELM to integrate a notably overlapping range of “active” learning activities. It then defined a Pedagogic Continuum, based on McLuhan (1964) and Allen & Seaman (2010 - 2016), of the directness and immediacy (“hotness”) of instructor contact with which to evaluate distance learning pedagogies. Intuitively, development of virtual courses should initially proceed using intermediate alternatives on the Continuum (Figure 2, position #3), particularly for
undergraduate, qualitative, or behavioral courses. Those courses, as well as computational, graduate, and quantitative courses, might then pursue virtual pedagogies (positions #4 and #5).

This study evaluated six sections of a business statistics course with traditional and virtual pedagogies (Figure 2, positions #2 and #3). Externalities carefully considered variation due to student-course-section selection. The design isolated three possible externalities (Major, Age, and Class), which, though not significant, might have been associated with some of the student performance differences in the EL section. However, on three dimensions, there were no differences between traditional and virtual pedagogies (the ELM Phase 2 effect). But, on those same dimensions, marginally significant or significant performance differences were found between EL and non-EL pedagogies (the ELM Phase 1 effect). The traditional and virtual pedagogies in this study represented the rather proximate positions of #2 and #3 on the Pedagogic Continuum, which may explain the relatively low significance of these findings. An evaluation of more diverse pedagogies might yield more significant outcomes. In each case, the inclusion of an EL component (Phase 1) improves on the Phase 2 Effect, virtual vs traditional. These outcomes are summarized at Table #5.

<table>
<thead>
<tr>
<th>Hypothesized Dimension</th>
<th>The Phase 2 Effect</th>
<th>The Phase 1 Effect</th>
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</thead>
<tbody>
<tr>
<td>Performance Improvement</td>
<td>(H01) No Difference</td>
<td>(H02) EL Score Improved More</td>
</tr>
<tr>
<td></td>
<td>p = .21</td>
<td>p &lt; .05</td>
</tr>
<tr>
<td>1st Cycle vs 3rd Cycle</td>
<td>(H03) No Difference</td>
<td>(H04) EL Decreased Less from 1st to 3rd Cycle</td>
</tr>
<tr>
<td></td>
<td>p = .73</td>
<td>p = .078</td>
</tr>
<tr>
<td>Qualitative vs Quantitative</td>
<td>(H05) No Difference</td>
<td>(H06) EL Decreased Less w/Quantitative</td>
</tr>
<tr>
<td></td>
<td>p = .50</td>
<td>p = .093</td>
</tr>
</tbody>
</table>

Simply put, this study has demonstrated that:

1) Completion of business statistics courses by undergraduate students improved their understanding of the field at a very high significance level, regardless of the pedagogy.

2) The effect of externalities on learning improvement was identified by the experimental design and explanations of those possible impacts were offered.

3) The traditional or virtual pedagogy by which the sections were taught (the Phase 2 Effect) did not result in either statistically significant or even marginal differences in student responses on any of the three basic dimensions (improved learning, 1st to 3rd cycle learning, and qualitative or quantitative learning) of the study.

4) The EL section outperformed, with marginal or better significance, the non-EL sections in the aggregate on each of the three dimensions (improved learning, 1st to 3rd cycle learning, and qualitative or quantitative learning) of the study (the Phase 1 Effect).
These results confirm that carefully designed studies that account for externalities do not find differences in student learning based on traditional vs virtual pedagogies (the Phase 2 Effect). Further, these results confirm that an engaged learning component (the Phase 1 Effect) effectively reinforces learning outcomes, particularly in the case of the less engaged virtual pedagogic formats. This conclusion reaffirms that the more convenient, generally lower cost, and more readily accessible virtual pedagogies for undergraduate business statistics courses, and likely other undergraduate quantitative courses, do not result in a degradation of student learning. In fact, this study shows that the use of virtual pedagogies may improve the learning experience of traditional pedagogies, particularly when combined with an engaged learning component.

This study has several strengths and makes several contributions to the body of knowledge, as well as several weaknesses. Initially, this study demonstrated that use of a well-constructed design can identify the impact of externalities. In this case, differing student backgrounds of Major, Age, and Class were likely reflected in the student course-section-selection process, but were explained and shown to have relatively little overall impact. Secondly, this study found that virtual technologies can result in learning outcomes, measured on three dimensions, which are statistically equivalent to those of traditional courses. Certainly, learning outcomes of the virtual sections are not degraded. Thirdly, this study found that, based on overall improvement, difficulty level of material and qualitative / quantitative content, there is no significant difference in performance between the traditional and virtual sections. However, fourthly, an engaged learning component can notably improve learning and enhance the effects of virtual pedagogies on these three dimensions.

However, two weaknesses are also suggested by this study. Initially, virtual section students attended less regularly than traditional students; perhaps those students felt that they could learn the material by accessing the videos. In fact, the course failure rate of one virtual section in the fall semester was somewhat higher than for traditional sections. This begs questions about undergraduate student maturity (predominantly Frosh and Sophomores) and preparedness for a pedagogy that may require more individual self-discipline. Further, the virtual pedagogy does not give the instructor the directness and immediacy of contact with the students that might potentially forestall such course failures. These concerns are addressed by Dutton, Dutton, & Perry (2002). Secondly, general performance on the post-survey was about 50% correct, which may be viewed as lower than expected. Yet, this was an unannounced and unrewarded activity. Survey questions were drawn from supplemental materials of other texts and were not specifically covered in the course. In a sense, the survey questions represent a broad and general understanding of retained basic statistics principles and processes. As such, the roughly 50% correct response rate for the “after” survey is felt to be a reasonable gauge.

Perhaps, however, the most notable contribution of this study is to address a range of methods to balance low-cost, convenient course access with quality, and to specifically design a strategy to implement virtual pedagogies, based on the needs of the academic program. Without this balance, low-cost convenient access, course quality, or both, may be degraded. In fact, the enhanced learning component and other active learning aspects of the ELM have been shown to mitigate this potential degradation and to enhance learning outcomes. Of course, replication in other populations and different courses is necessary to affirm these results; however, this study has offered an effective model for those efforts, and a reasonably credible basis to support the further development and use of a range of virtual learning pedagogies.
References


Appendix 1

Assessment Survey #1  Business Statistics
Closed Book

This survey will be used for assessment purposes as a part of the School of Business Accreditation process. Additionally, the researchers may publish articles on the aggregate outcomes of this data. No names will ever be associated with individual survey results, and the outcomes will only be published in the aggregate and without individually identifying information.

1. A simple random sample is defined as:
   a. the selection of all observations in a population
   b. the collection and description of data
   c. a data set in which any value over a particular range is acceptable
   d. a sample in which each item in a population has an equal chance of selection

2. Which method of measuring data shows a meaningful sequence of the data and a meaningful difference of data values?
   a. nominal
   b. ordinal
   c. interval
   d. ratio

3. Which of the following are characteristics of a frequency polygon?
   1. a graph that represents the shape of the data
   2. a series of bars that represent the distribution of data
   3. the connection of the mid-points of classes
   4. a graph used to represent nominal and ordinal data only
   a. 1 and 3 only
   b. 1 and 4 only
   c. 2 and 3 only
   d. 2 and 4 only

4. Which of the following statements is correct with regard to calculating frequency distributions?
   a. the number of classes (k) is too small if ≥ 50% of values are in one class
   b. the class width (cw) is too narrow if ≥ 50% of values are in one class
   c. the class width is calculated by the formula: (range / number of classes)
   d. the class width and limits can be calculated without regard to the number of classes

5. Which is NOT a measure of the dispersion of a data set?
   a. variance
   b. range
   c. mode
   d. standard deviation
6. What is the median of the following 7 values? 3.2, 2.8, 4.3, 5.0, 3.5, 4.4, 4.8
   a. 5.2
   b. 4.0
   c. 4.3
   d. 5.0

7. Which of the following is **NOT** a measure of position?
   a. the median
   b. kurtosis
   c. the first quartile
   d. the second decile

8. Which of the following is correct with regard to the skewness of data?
   a. Negatively (left) skewed data has a (mode – mean) = negative
   b. Positively (right) skewed data has a (mean – median) = positive
   c. Skewed data has the same proportion of observations on each side of the mean
   d. Skewed data is always very peaked

9. Which of the following are among the three types of probability?
   1) Classical probability
   2) Empirical probability
   3) Sampling probability
   4) Bayesian (Subjective) probability
   a. 1, 2, and 3
   b. 1, 2, and 4
   c. 1, 3, and 4
   d. 2, 3, and 4

10. Given the information in the associated table:

<table>
<thead>
<tr>
<th>Gender</th>
<th>Age (Years)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>&lt; 30</td>
</tr>
<tr>
<td>Female</td>
<td>60</td>
</tr>
<tr>
<td>Male</td>
<td>40</td>
</tr>
<tr>
<td>Total</td>
<td>100</td>
</tr>
</tbody>
</table>

   a. the marginal probability for males is .60
   b. the joint probability of female and 30-45 years is .30
   c. the probability of either male or > 45 is .60
   d. the probability of either female or male is 0.00

11. Which of the following statements is true?
   a. Probabilities can only be measured in situations where replacement is NOT possible
   b. There are three types of counting rules: combinations, permutations, and filling slots
   c. Bayesian (subjective) probabilities deal with a probability measure from 0 to infinity
   d. The Binomial and Poisson distributions are used to evaluate normal data

12. What is the probability of getting two heads out of four flips of a fair coin?
   a. 30%
   b. 33.3%
   c. 37.5%
   d. 50%
13. Which of the following is **NOT** a characteristic of the normal distribution?

a. It is symmetric in shape  
b. It represents a continuous random variable  
c. The arithmetic mean, median, and mode are equal  
d. The values of a normal distribution can only be positive

14. If the mean of a sample of employee monthly salary data is $2,500 and the standard deviation is $250, what is the range within which approximately 95% of observations would be expected?

a. $2,000 - $3,000  
b. $2,250 - $2,750  
c. $2,375 - $2,625  
d. cannot be determined from the given data.

15. The central limit theorem permits statisticians to:

a. use the t-distribution for large samples  
b. assume a normal distribution with most large data samples  
c. establish confidence intervals for small data sets  
d. evaluate data using point estimates and confidence intervals

16. Which of the following statements is **FALSE**?

a. The mean of the distribution of the sample mean is equal to that of the population mean  
b. The distribution of the sampling mean is always less than the distribution of the population mean  
c. The mode of the sample is the same as that of the population  
d. The t table and the Z table will give the same value if the same parameters are used

17. When setting up a hypothesis test, the statistician must assure that:

a. The “boastful claim” is placed in the H-null (null hypothesis)  
b. The equality is placed in the H-null (null hypothesis)  
c. The H-alternative (alternate hypothesis) contains the status quo statement  
d. Both one- and two-tailed hypothesis tests are included

18. To calculate a confidence interval of a sample using a proposed Z value, which of the below factors is added or subtracted from the sample mean:

a. The Z value times the square root of the sample size divided by the sample standard deviation  
b. The Z value times the sample standard deviation  
c. The Z value times the sample standard deviation divided by the square root of the sample size  
d. The Z value times the square root of the sample size

19. Which of the following is **NOT** a correct way to differentiate types of hypothesis tests?

a. One vs two samples  
b. Right vs left tail hypotheses  
c. Dependent vs independent samples  
d. Alpha vs beta errors
20. A 95% confidence level or a 5% error means an expectation of:
   a. Less than one error in 100
   b. About one error in twenty
   c. More than one error in ten
   d. A high confidence outcome

21. Two sample tests are available for all of the following, except:
   a. a comparison of the variance of two normal populations
   b. a binomial test of two population means
   c. a test of the means of two dependent samples
   d. a test of the means of two large samples

22. When using a t-test, the number of degrees of freedom is based on:
   a. the number of samples of both populations
   b. subtracting the number of averaged variables from the sample size
   c. the degrees of freedom equals the sample size, if the sample size is > 30
   d. the degrees of freedom is equal to one less than the largest sample

23. Which of the following statements about evaluation of data using the F test is true?
   a. the F test evaluates the standard deviations of two samples or populations
   b. the F test involves rejection regions that are both positive
   c. the F test shows which means of multiple populations are different
   d. because the F distribution is positive, the F test may be only used for a right tail test

24. The one-factor analysis of variance (ANOVA) test assumes all of the following, except:
   a. the sampled populations have a common variance
   b. all sampled population means are different
   c. all observations are random and independent
   d. the observations from each population are approximately normal

25. Regression analysis may be used to evaluate all of the following, except:
   a. evaluate the y-intercept and slope of bivariate or multivariate data
   b. assess the randomness of a data set
   c. estimate the confidence interval and prediction intervals around the regression line
   d. test the significance of the coefficient of each slope variable

26. In simple linear regression analysis, which of the following lines are arced.

   1) The prediction interval
   2) The standard deviation
   3) The confidence interval
   4) The regression line

   a. 1 and 2
   b. 1 and 3
   c. 2 and 3
   d. 3 and 4
Demographics

Student id number (put number directly in space at upper left)

Ignore the phone #, the name information, the code, the test form, and the subj score.

PLEASE SKIP TO RESPONSE LOCATION #31

31. Section of Statistics Course
   a. Engaged Learning Section
   b. Traditional Section
   c. Voluntary Virtual Hybrid

32. My gender is:
   a. Female
   b. Male

33. My age (based on my most recent birthday) is:
   a. < 18 years old
   b. 18 – 20 years old
   c. 21 – 24 years old
   d. 25 – 28 years old
   e. > 28 years old

34. What is your class?
   a. Freshman
   b. Sophomore
   c. Junior
   d. Senior
   e. Other

35. My current employment status
   a. I am not currently employed (not working for either the university or private employment)
   b. I am employed < 21 hours / week (either university or private employment)
   c. I am employed 21 – 35 hours / week (either university or private employment)
   d. I am employed > 35 hours / week (either university or private employment)

36. I live:
   a. At home with my parents or a relative
   b. In a university dorm
   c. In a non-university-owned apartment

37. Have you previously completed another statistics course
   a. Yes – An Advanced Placement Statistics Course in High School
   b. Yes – A college-level statistics course before taking my current business statistics course
   c. No

38. My current, or expected major is in the:
   a. The School of Business
   b. The School of Arts & Sciences
   c. The School of Education
   d. The Schools of Nursing or Medicine
   e. Other or undecided

Thank you for your participation.
Active Teaching as a Moderator of Course Difficulty

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Abstract

Given the recent reported common occurrence of student mediocre or substandard academic performance in colleges and universities, it has become essential to identify pedagogical factors that might lessen or reverse this trend. Kolb's experiential learning, Pintrich's student learning motivation, and cognitive load theories were used as a framework to assess active teaching moderation of course difficulty effects on course performance and learning motivation. Hierarchal OLS regression was used to analyze the data. Research subjects were recruited from a medium-sized historically Black college and university (HBCU) students enrolled in STEM (science, technology, engineering mathematics) and Business (i.e., management, economics, or accounting) classes. Active teaching was a positive predictor of course grade and learning motivation. Course difficulty was a negative predictor of course grade. Interaction analysis revealed that increases in active teaching reduced (i.e. moderated) the negative relationship between course difficulty on both course grade and learning motivation. Overall, the findings suggests that student learning outcomes are certainly a function of pedagogy (e.g., active teaching), psychological/affective (e.g., learning motivation) and learning content complexity. Active teaching environments should (1) address both cognitive load and affective responses attributed to difficult coursework, and (2) provide efficacy building opportunities during instructional delivery.

Keywords: active teaching, cognitive load, course difficulty, experiential learning, learning motivation, simple slope

Introduction

Student mediocre performance and quality of the teaching and learning environment have increasingly become an important agenda in universities and colleges (OECD, 2013). Use of experts in the education quality assurance field and internal learning assurance committees are among the strategies that have been employed to help define and ensure implementation of methods for monitoring, evaluating, and improving the quality of teaching (Chen, Chen, & Chen, 2014). The quality of teaching pedagogy and innovative teaching approaches have been defined as critical components in addressing declines in student performance, enrollment, retention, and graduation rates (Balotsky, Stagliano, & Haub, 2016). In efforts to innovate, universities have begun to make a shift toward an active/experiential teaching and learning paradigm where emphasis is placed on student–student and student–teacher collaboration, and activities that require greater student engagement in the learning process. This pedagogy paradigm shift represents a significant contrast to traditional instructional delivery that consists of passive
lectures where teachers verbally communicate information to the students, and students passively receive and encode it in their memory.

One of the hallmarks of an active/experiential teaching strategy is that it promotes student engagement in the learning process by the use of multiple modes of instructional delivery (e.g., video, text, images) and requiring students to take notes, write, discuss, and reflect on learning content. In addition, applying concepts via guided in-class exercises accompanied with real world examples is also a feature of active/experiential learning (Mikalayeva, 2016; Peterson, DeCato, & Kolb, 2015). Although active learning has traditionally been associated with positive learning outcomes (Naveh, Katz-Navon, & Stern, 2015), some researchers have noted that active learning may be dysfunctional under certain circumstances and it is not yet clear why active teaching/learning succeeds or fails in real-world settings (Markant, Ruggeri, Gureckis, & Xu, 2016). It is suggested that negative or equivocal findings associated with active learning could have been attributed to the presence of overlooked individual, learning task, or task setting characteristics that moderated learning outcomes. The present study also suggests that an interactionist approach can help to discover better fitting research models that provide greater understanding and predictive power. This study addresses that research gap by specifically testing for a moderating effect of active teaching on course difficulty and the potential to enhance learning task value and intrinsic motivation.

The theoretical framework proposed in this study incorporates Kolb's theory of experiential learning (Kolb & Kolb, 2005; Peterson et al., 2015), the learning motivation framework by Pintrich (2003, 2004), and cognitive load theory (Sweller, 2010). The integration of these frameworks allow the examination of the teaching and learning process on four levels – 1) attention/engagement, 2) encoding, 3) information processing/synthesizing and 4) motivation.

The specific research questions addressed in this project are:

- Can the active teaching style, as compared to passive lecture-based teaching, result in significantly better student course performance and learning motivation?
- Can active teaching moderate effects of course difficulty on course performance and learning motivation?

In what follows, the next section reviews the relevant literature on active/experiential learning, cognitive processing, and the role of psychological/mental states in determining student academic performance. This is followed by the presentation of the research model and hypotheses. The next two sections describe the research methodology and results, respectively. Finally, discussion of the findings, implications, and suggestions for future research is presented.

**Literature Review**

**Active and Experiential Learning Environment**

Kolb’s Experiential Learning Theory (Kolb & Kolb, 2005; Peterson et al., 2015) has defined experiential learning as a process whereby knowledge transfer is facilitated through 1) sensory
(e.g., visual, auditory, tactile), 2) mental (e.g., attention, perception, sense-making) and, 3) concrete participative (e.g., physical task performance) experience. As shown in Figure 1, Kolb’s model depicts a cyclical four-phase process: concrete experience; reflective observation; abstract conceptualization; and active experimentation. The model suggests that a learner must experience, reflect, think, and apply learned content in a cyclical process. Concrete experience is realized when the learner is able to actively perform activities relevant to the learning objective. During the process of reflective observation, the learner consciously observes and reflects on their concrete experience to encode and organize information inherently made available through task performance. Abstract conceptualization is characterized by analysis, inferences, and conclusions derived from acquired information to construct a mental model of the learned concepts. This is followed with active experimentation where acquired knowledge is then applied to confirm comprehension.

![Figure 1. Kolb’s Experiential Learning Theory](image)

From an practitioner perspective, an active learning environment has been characterized by the use of a variety of instructional delivery modes that include videos/multimedia presentations, note-taking, class discussions, group work, repetitive guided in-class exercises, and the use of periodic learning assessment quizzes (Mikalayeva, 2016; To & Carless, 2016). Past research (e.g., Mayer, Lee, & Peebles, 2014; Morena, 2007) has shown that videos, multimedia presentations, and diagrams can augment cognitive processing by 1) minimizing explanatory content by summarizing distinctive features or procedures, 2) clarifying abstract concepts, 3) facilitating long-term memory via memorable mnemonic, and 4) sustaining student attention, mental effort, and learning satisfaction through perceptual arousal.

**Learning Goal Orientation**

In a review of research on motivation, Eccles (2009) noted that extrinsic and intrinsic motivation, task value and interest, and theories on the integration of cognition and motivation were among the main research streams examined. In this review, perceived task challenge, task difficulty, task value, and task interest were identified as important components of goal orientation which
determines the intensity of the intention to act, level of applied effort, and persistence towards goal achievement. Pintrich (2003, 2004) referred to intrinsic motivation toward a learning task as participation for reasons such as curiosity or desire for task mastery. In contrast, extrinsic motivation was said to stimulate task execution intentions based on desire to obtain a reward or avoid a loss (e.g., high or low course grade), expectations of others, or perceived importance (e.g., value of college degree). Task value refers to the student's evaluation of the how interesting, how important, or the extent of usefulness of the knowledge and skill associated with the learning task. A learning environment can stimulate students' intrinsic motivation by providing tasks and activities that offer the opportunity to and expectancy to achieve skill and task mastery and derive satisfaction from experienced success and goal attainment (Adcroft, 2011; Orsini, Evans, Binnie, Ledezma, & Fuentes, 2016). In contrast, tasks that are unattainable, difficult, or vague have been shown be result in diminished task interest or task effort, and possibly task withdrawal (Locke & Latham, 2002).

Cognitive Load in Learning Tasks

Cognitive load theory can be used as a theoretical framework for investigating the influence of teaching approach in supporting the cognitive processing demands of courses with highly complex information content (Sweller, 2010). Sweller (2010) distinguished three types of cognitive load - intrinsic, extraneous, and germane. Intrinsic cognitive load cannot be altered and is generated by the level of information complexity (e.g., number of ideas simultaneously considered, number of steps or causal chains among ideas) of a learning task. For example, keystroke sequence for printing a photograph in a Photoshop application is an example of low element interactivity while simultaneously changing the brightness, color and contrast in a photo requires consideration of one's effect on the other and thus represents higher element interactivity. Extraneous cognitive load can be altered and is caused by unnecessary information or poor instructional design that imposes inefficient and ineffective cognitive processing. Germane cognitive load refers to resources used to deal with the intrinsic cognitive load in working memory for the construction and organization of mental models (i.e. knowledge) in long term memory. Cognitive load theory suggests that instructional methods should address a student's limited cognitive/information processing capacity and minimize the cognitive load associated with the material to be learned. Specific instructional strategies reported to have reduced cognitive load include, multimedia presentation, direct manipulation via hands-on activities, instructor guidance, presentation of and practice using worked examples, and reflective discussions (e.g., Chen, Kalyuga, & Swellar, 2015; Hsu, Kalyuga, & Sweller, 2015; Moreno, 2007).

Research Model and Hypotheses

The proposed research model in Figure 2 facilitated addressing the earlier stated research questions. The extent of active teaching for experiential learning and course difficulty were tested for potential impact on academic outcomes (e.g., course grade, learning motivation). In addition, the potential moderating or interaction effects of active teaching and course difficulty impact on course grade and learning motivation were also examined.
Hypotheses

**Active/Experiential Learning and Learning Outcomes**

As noted earlier, past research (e.g., Mayer et al., 2014; Morena, 2007; Pedra, Mayer, & Albertin, 2015) has shown that active teaching tactics such as use of videos and diagrams can reduce cognitive load by eliminating the need to manually convert text or verbal information into visual imagery of an object or process and the need to simulate a process in memory. Note-taking was also found to help improve learning and test performance through required active student engagement, content reinforcement, and by summarizing and identifying important content (Bui, Myerson, & Hale, 2013; Katayama, Shambaugh, & Doctor, 2005; Wetzels, Kester, van Merriënboer, Broers, 2011). Class discussions and group work have been associated with improved learning through a *cumulativity* process where students build on their own, each other’s, and teacher knowledge via dialogue (Dyer & Hurd, 2016; Hodgson, Benson, & Brack, 2015; Lehesvuori, Viiri, Raksu-Puttonen, Moate, & Helaakoski, 2013). Frequent practice activities and tests/quizzes were revealed to encourage students to stay on task, provide reinforcement and clarification opportunities, and promote long term retention (Basol & Johanson, 2009; Dyer & Hurd, 2016). Finally, repetitive instructor guidance through worked examples provided concrete experience and active manipulation needed for comprehension, application, and retention.

Studies have shown that when teachers offer an experiential learning and mastery-oriented classroom climate, students can become motivated to invest more effort and use deeper learning strategies (Banfield & Wilkerson, 2014; Bolkan, 2015; Reeve & Lee, 2014). The aforementioned studies suggest that course difficulty manifested from associated cognitive load can impact academic performance. In addition, active teaching could moderate negative effects of course difficulty on course performance by mitigating extraneous load and enhancing germane load processing. In other words, differences in low versus high course difficulty effects on course grade would be reduced as active teaching is increased. Consequently, the following hypotheses are proposed:
**H1a:** Increases in the use of active teaching methods will be associated with increases in student course performance.

**H1b:** Increases in the use of active teaching methods will be associated with increases in student learning motivation.

**H1c:** Active teaching will moderate the negative effect of course difficulty on course grade, in that course difficulty will have less of a negative effect on course grade at higher levels of active teaching.

**Course Difficulty Outcomes**

Courses can exhibit differences in task and information complexity. For example, computer programming has been demonstrated to be a task characterized by high concept (element) interactivity (Stachel, Marghitu, Brahim, Sims, Reynolds, & Czelusniak, 2013). The high element interactivity is attributed to requirement to simultaneously to understand and apply logic and mathematical concepts, programming language syntax, and algorithms. Stachel et al. (2013) noted that the use of scaffolding (e.g., progressive disclosure, concept sequencing, instructor controlled guidance) helped to reduce cognitive load and improve computer programming course scores. In contrast, the control group (no instructor guidance) received lower course scores and reported higher levels of stress and frustration. Hsu et al. (2015) provided instructional guidance via worked examples and supplementary materials for practice and review and observed superior physics content learning transfer attributed to reduced cognitive load relative to the non-guidance control group. In a similar study, Chen et al. (2015) specifically minimized irrelevant content and manipulated element interactivity in geometry instruction which resulted in better test performance as compared to conditions with irrelevant content and higher element interactivity. Cognitive load was reduced by providing direct knowledge (i.e., a worked example) transfer that did not require student self-processing and solution step sequencing typical to moving from an unsolved problem to a solution. In summary, course difficulty has demonstrated a tendency to lower course grades but this negative effect could be reduced (i.e. moderated) by active teaching techniques.

Locke and Latham (2002) noted that, to maximize task motivation, a task should be designed to be attainable and provide optimal challenge (i.e., equal to or slightly beyond skill level). This suggests that a learning task setting should implement a task design and teaching approach that would lessen the tendency for diminished learning motivation typically attributed to course task difficulty. Video/multimedia presentations, timely and constructive feedback, teamwork, and team discussion (i.e., experiential learning) have been shown to lead to increased student intrinsic motivation (Lin, Atkinson, Savenye, & Nelson, 2016; Orsini et al., 2016). For example, using a multimedia game-like presentation on computer-aided manufacturing, Woo (2014) observed increased learning motivation and learning effectiveness both of which were attributed to reductions in cognitive load. As such, differences in low versus high course difficulty effects on learning motivation would be reduced as active teaching increased. These studies suggest the following hypotheses:
H2a: Increases in course difficulty will be associated with decreases in student course performance.

H2b: Increases in course difficulty will be associated with decreases in student learning motivation.

H2c: Active teaching will moderate the negative effect of course difficulty on learning motivation, in that course difficulty will have less of a negative effect on learning motivation at higher levels of active teaching.

Research Methodology

Participants

To test the research hypotheses, a sample of respondents from a medium-sized historically Black college and university (HBCU) were recruited. This purposeful sampling approach (i.e., specific setting, persons, or events - Gravetter & Wallnau, 2012) was used to address the extant level of active teaching pedagogy and related research conducted in HBCUs. The majority of recent research in HBCU settings has focused on social and institutional factors that impact persistence and graduation rates (e.g., Longmire-Avital & Miller-Dyce, 2015). Out of a total pool of 489 potential participants, 307 completed the questionnaire and 294 responses were usable, thus representing a 60% response rate. The participants included 109 (37%) females and 185 (63%) males. Black/African American constituted 84% of the participants with 7% White, 4% Asian, 2% Hispanic, and 3% other race remaining. Most participants (45%) were of age 21 to 23 followed by 18 to 20 (42%) and above 23 (13%). The majority of the sample (64%) indicated that their families earn an average income, 33% reported below average income, and 3% above average incomes. The average GPA was 3.0 and 37% of the participants reported a high school GPA above 3.5, while 3.1 to 3.5, 2.6 to 3.0, and 2.0 to 2.5 were 37%, 20%, and 6%, respectively. Table 1 depicts demographic characteristics of the subjects.

Table 1. Research Sample Characteristics

<table>
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<tr>
<th>Socio-demographic</th>
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<th>%</th>
<th>N</th>
<th>%</th>
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Measures

Dependent variables. The final grade earned in the course was used as one of the dependent variables. Learning motivation was adapted from the intrinsic motivation and task value subscales of the motivated strategies for learning questionnaire (MSLQ) by Pintrich (2003, 2004). The MSLQ scales assess students’ intrinsic motivation and task value toward the course. Four Likert scale items (Cronbach's alpha = 0.70) were used for the learning motivation measure with response options ranging from (1) never to (5) always. Students were asked to rate their interest in mastery of the learning task (e.g., "I keep studying until I understand a topic completely") and task value/interest (e.g., "The topics discussed in this class were interesting to me").

Independent variables. On all scales, responses ranged on a five-point Likert scale from 1 (never) to 5 (always). The active teaching style was assessed with four items (Cronbach's alpha = .64) that are consistent with the five processes defined in Kolb's Experiential Learning Theory (Kolb & Kolb, 2005; e.g., "This teacher guided us step-by-step when explaining topics," "This teacher allowed us to do some of the work in groups"). Course difficulty was measured using a single item scale ("The coursework in this class was difficult") (e.g., Wu, Bieber, & Hiltz, 2008). Single item scales that are salient, narrow in scope, one-dimensional, and unambiguous as well as small multiple item scales have been shown to provide valid and reliable scores of
traits measured (Diamantopoulos, Sarstedt, Fuchs, Wilczynski, & Kaiser, 2012). Single item scale have also been shown to exhibit reliability and validity similar to or even superior to larger scales with homogeneous redundant items that tap into the same concept (Fisher, Matthews, & Gibbons, 2016). Although, construct reliability is possible for single item measures, it does not allow for internal consistency (i.e., Cronbach's alpha) assessment. The course difficulty single item scale exhibited construct validity through convergent evidence via high correlation with like constructs and discriminant evidence via low and negative correlation with dissimilar constructs (Chmielewski, Sala, Tang, & Baldwin, 2016). Construct validity (i.e., measures what it is intended to measure) is considered the overarching validity subsuming all other forms of reliability and validity (Gravetter & Wallnau, 2012).

Control variables. Academic and socio-demographic control variables shown to be relevant in prior research (e.g., Beattie & Thiele, 2016; Chingos, 2016) were used to isolate the net influence of active teaching and course difficulty on the dependent variables (see Table 1). The academic control variables were current college GPA, year in school (e.g., freshman, sophomore), and class type (e.g., STEM - chemistry, computer science, engineering or mathematics and Business - management, economics, or accounting). Class size, course enrollment load, and attendance were also used as academic control variables. The socio-demographic control variables used were gender, race, and age.

Analyses

The hypotheses were tested using multiple hierarchical OLS regression analyses to control for any variability not accounted for by the independent variables - active teaching and course difficulty. In the first step (or block), the socio-demographic background control variables were entered as a group to assess their contribution to variability in the outcome variables - course grade and student learning motivation. The academic control variables were entered in the second step to account for any variability associated academic factors. Finally, the independent variables were entered to isolate their effects. The typical assumptions for OLS regression statistical analyses (e.g., normality, homogeneity of variance, multicollinearity, outliers, and independence of observations) were tested and no significant abnormalities were found. The observed missing data was characterized as MAR (Missing data at Random) and missing values were replaced by the series mean multiple imputation method (Enders, 2010; Graham, 2012). Preliminary analysis revealed that gender, race, age, GPA, enrollment, and attendance were the only control variables found to be significant with either course grade or learning motivation and thus all others were dropped in the final analysis.

Results

Descriptive statistics and bivariate correlations among the variables are reported in the correlation table presented in Table 2. Pearson correlations in Table 2 reveal that White students ($r = 0.16, p < .01$) were positively correlated with course grade and Black students were negatively correlated ($r = -0.17, p < .01$). Asian students were also positively correlated with current GPA ($r = 0.12, p < .05$) and learning motivation ($r = 0.13, p < .05$). Current GPA was positively correlated with White students ($r = 0.15, p < .05$), course grade ($r = 0.56, p < .01$),
and active teaching ($r = 0.24, p < .01$) but negatively correlated with Black students ($r = -0.16, p < \cdot 01$) and course difficulty ($r = -0.16, p < .01$). The age group of students above 23 years were positively correlated with course grade ($r = 0.17 p < .01$) and learning motivation ($r = 0.19 p < .01$). Current GPA was also positively correlated with enrollment above 15 credit hours ($r = 0.15 p < .01$) and absence rate of 3 days or less ($r = 0.12 p < .05$) and negatively correlated with STEM class type ($r = -0.32, p < .01$), class size ($r = -0.12, p < .05$), enrollment between 12 and 15 credit hours ($r = -0.15, p < .01$), and absence rates between 4 and 4 days ($r = -0.15, p < .01$). Sophomores were negatively correlated with course grade ($r = -0.15, p < .01$). Class size was negatively linked to course grade ($r = -0.12, p < .05$). Enrollment below 12 credit hours was positively correlated with course difficulty ($r = 0.16, p < .01$). In contrast, enrollment of more than 15 credit hours was negatively correlated with course difficulty ($r = -0.14, p < .01$). Course grade ($r = 0.17, p < .01$) and learning motivation ($r = 0.16, p < .01$) were both positively correlated with absence of 0 to 3 days. In contrast, course grade ($r = -0.18, p < .01$) and learning motivation ($r = -0.20, p < .01$) were negatively correlated with absence of 4 to 6 days. Despite evidence of correlations among the independent variables, the use of summated scales and SPSS tolerance and variance inflation (VIF) scores suggested that multicollinearity was not an issue in this study (Rutherford, Parks, Cavazos, & White, 2012; Segura, Sarkani, & Mazzuchi, 2013).

Table 2. Descriptive Statistics and Intercorrelations

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<th>5</th>
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<td>-0.04</td>
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Dependent
23. Course Grade  
24. Motivation  
Explanatory  
25. Active Teaching  
26. Course Difficulty  

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N = 294

† Correlation is significant at the 0.01 level 2-tailed.
* Correlation is significant at the 0.05 level 2-tailed.
— indicates dummy variable
a Female is the reference category for Gender
b STEM is the reference category for Class Type

Table 2. Descriptive Statistics and Intercorrelations (continued)
* Correlation is significant at the 0.05 level 2-tailed.
— indicates dummy variable
a Female is the reference category for Gender
b STEM is the reference category for Class Type

Table 2. Descriptive Statistics and Intercorrelations (continued)

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<tr>
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<td>0.01</td>
<td>0.02</td>
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<td>0.07</td>
<td>-0.14*</td>
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<td><strong>N = 294</strong></td>
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† Correlation is significant at the 0.01 level 2-tailed.
* Correlation is significant at the 0.05 level 2-tailed.
— indicates dummy variable
a Female is the reference category for Gender
b STEM is the reference category for Class Type

Table 2. Descriptive Statistics and Intercorrelations (continued)

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<td>-0.19†</td>
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<tr>
<td><strong>Std. Dev.</strong></td>
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<td><strong>N = 294</strong></td>
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</table>
Regression analysis was used to test the hypotheses. The socio-demographic and academic control variables and explanatory variables (i.e., active teaching and course difficulty) were initially analyzed for significant effects on course grade and learning motivation. The socio-demographic included were gender, race, and age. The academic control variables were college GPA, year in school (e.g., freshman, sophomore, etc.), class type (i.e., STEM or Business), class size, course enrollment load, and attendance rate. To maximize statistical power and utilize a more parsimonious model, all control variables that were not significant to the prediction of course grade or learning motivation were dropped in the final analysis for each dependent variable.

Table 3 shows that in the regression analysis used to predict course grade, the model was significant ($F = 68.712, p < .001, R^2 = 0.544$) and accounted for 54.4% of the variance in course grade. The White students category ($β = 0.09, p < .05$) and the college GPA ($β = 0.42, p < .01$) were the only control variables that were significant predictors of course grade. Active teaching ($β = 0.22, p < .05$) was a positive predictor of course grade providing support for Hypothesis 1a. As expected, course difficulty ($β = -0.39, p < .01$) was a significant negative predictor of course grade and thus provided support for Hypothesis 1b. This is visually evidenced by the negative slopes of the regression lines in Figure 3.

Table 3. Regression Standardized Coefficients

<table>
<thead>
<tr>
<th>Variable</th>
<th>β</th>
<th>Sig.</th>
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<td>0.028</td>
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<tr>
<td>AT x CD</td>
<td>0.29*</td>
<td>0.040</td>
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</tbody>
</table>

$R^2 = 0.544$  Adj. $R^2 = 0.536$

$F = 68.712$  Sig. $F$ Change $= 0.000$

†$p < .001$  **$p < 0.01$  *$p < 0.05$
The interaction of active teaching and course difficulty ($\beta = 0.29, p < .05$) exhibited a significant positive effect on course grade ($f^2 = .50$) and thus provided support for Hypothesis 1c. Figure 3 visually depicts how the effect of course difficulty on course grade varied as a function of increases in active teaching. The mean and one standard deviation above and below the mean of active teaching were used to compute the anchors for the regression slopes of course grade predicted by levels of course difficulty (Cohen, Cohen, West, & Aiken, 2003).

As seen in Figure 3, for each level of active teaching, high course difficulty resulted in lower course grade as compared to low course difficulty. Simple slope tests (e.g., Aiken & West, 1991; Dawson, 2014) indicated that the slope corresponding to low active teaching ($t_{290} = -2.71$, $p < .05$) differed significantly from zero while a medium ($t_{290} = -1.74$, $p = .08$) and a high degree of active teaching ($t_{290} = -0.74$, $p = .46$) did not significantly differ from zero. This suggests that under low active teaching conditions, course difficulty was able to negatively affect course grade as evidenced by a significant slope. In contrast, insignificant slopes for medium and high active teaching suggest that, for these levels, low and high course difficulty did not result in significantly different course grades. In addition, course grades were higher at higher levels of active teaching under both low course difficulty and high course difficulty conditions. These interaction results provide support for Hypothesis 1c which states that course difficulty will have less of a negative effect on course grade at higher levels of active teaching.

As depicted in Table 4, in the regression analysis used to predict learning motivation, the model was significant ($F = 11.368, p < .001, R^2 = 0.218$) and accounted for 21.8% of the variance in learning motivation. The female students category ($\beta = -0.11, p < .05$), the age 21 to 23 group ($\beta = -0.12, p < .05$), and absent 4 to 6 day rates were significant negative predictors of learning motivation. Enrollment under 12 credit hours ($\beta = 0.12, p < .05$) was positively associated with learning motivation. Active teaching ($\beta = 0.61, p < .01$) was a positive predictor of learning motivation providing support for Hypothesis 2a. Contrary to expectations, course difficulty ($\beta = 0.21, p = .235$) was not a significant negative predictor of learning motivation and thus Hypothesis 2b was not supported.
Table 4. Regression Standardized Coefficients

<table>
<thead>
<tr>
<th>Variable</th>
<th>Learning Motivation</th>
<th>β</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Demographic Control</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Gender (female)</td>
<td>-0.11*</td>
<td>0.033</td>
<td></td>
</tr>
<tr>
<td>Age 21 - 23</td>
<td>-0.12*</td>
<td>0.035</td>
<td></td>
</tr>
<tr>
<td><strong>Academic Control</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Enrollment &lt; 12 cr.hrs.</td>
<td>0.12*</td>
<td>0.025</td>
<td></td>
</tr>
<tr>
<td>Absent 4 to 6 days</td>
<td>-0.14**</td>
<td>0.007</td>
<td></td>
</tr>
<tr>
<td><strong>Explanatory</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Active Teaching (AT)</td>
<td>0.61†</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>Course Difficulty (CD)</td>
<td>0.21</td>
<td>0.235</td>
<td></td>
</tr>
<tr>
<td>AT x CD</td>
<td>-0.37*</td>
<td>0.048</td>
<td></td>
</tr>
</tbody>
</table>

$R^2 = 0.218$  $\text{Adj. } R^2 = 0.199$  $F = 11.368$  $\text{Sig. } F \text{ Change} = 0.000$

†p < .001  **p < 0.01  *p < 0.05

The interaction of active teaching and course difficulty ($\beta = -0.37, p < .05$) exhibited a significant negative effect ($f^2 = .20$) on learning motivation and thus provided support for Hypothesis 2c. Figure 4 visually depicts how the effect of course difficulty on learning motivation varied as a function of increases in active teaching. The mean and one standard deviation above and below the mean of active teaching were used to compute the anchors for the regression slopes of learning motivation predicted by levels of course difficulty (Cohen et al., 2003).

As seen in Figure 4, for each level of active teaching, high course difficulty resulted in lower learning motivation as compared to low course difficulty. Simple tests (e.g., Aiken & West, 1991; Dawson, 2014) indicated that the slopes corresponding to a low ($t_{290} = 3.77, p < .05$), a medium ($t_{290} = 5.26, p < .001$), and a high degree of active teaching ($t_{290} = 4.52, p = .001$) differed significantly from zero. This suggests that under low, medium, and high active teaching conditions, course difficulty was able to attenuate learning motivation. In addition, learning motivation was higher at higher levels of active teaching under both low course difficulty and high course difficulty conditions. As such, at a given level of course difficulty, the capacity for course difficulty to lower learning motivation was weaker at higher levels of active teaching. These interaction results provide support for Hypothesis 2c which states that course difficulty will have less of a negative effect on learning motivation at higher levels of active teaching.
Discussion

The findings of this study revealed that academic performance and learning motivation are situational outcomes in that the extent of use of an active teaching approach was demonstrated to impact course grade by mitigating negative effects of course difficulty. Consistent with prior research (Banfield & Wilkerson, 2014; Bolkan, 2015; Reeve & Lee, 2014), increased levels of active teaching, with course difficulty held constant, resulted in higher course grades and maintained higher levels of learning motivation. It is suggested that active teaching primarily helps to overcome course difficulty through a *representational fluency effect* where concepts and ideas and their interrelationships are easier to internally visualize and process in short-term and long-term memory. Text, lecture, diagrams, multimedia, and demonstrations likely provided an increasing number and concrete representations of concepts to be learned as well as reduced cognitive load through visual and symbolic imagery needed to develop a mental model of a concept (Moore, Miller, Lesh, Stohlmann, & Kim, 2013). Further, it appears that active teaching is better able to moderate cognitive load imposed by course difficulty as compared to moderating affective responses typical to course difficulty (e.g., hopelessness, inability, or inevitable failure).

Although there was evidence of reduction in cognitive load via active teaching, course difficulty did demonstrate negative main effects on course grade. This is likely attributed to reported tendencies for more challenging learning tasks to exhibit high degrees of element interactivity and thus higher cognitive load. This was confirmed with impromptu post-study discussions with students regarding experienced course difficulty. A noteworthy finding lies in the fact that the moderation effect of active teaching of course difficulty impact on course grade was actually more effective under increased course difficulty conditions (see Figure 3). This is also evidenced by the positive active teaching and course difficulty interaction effect coefficient for course grade.

The lack of course difficulty main effects on learning motivation may have been attributed to students that enrolled in difficult courses intrinsically developed a sense of desire or urgency to meet task challenges. Response bias may have also been a contributing factor to lack of course
difficulty main effects on learning motivation. Studies have shown that for reasons such as social desirability or desire to appear diligent and conscientious, student self-reported ratings on goal orientation, task value, and task effort can be upward-biased (Humburg & van der Velden, 2015; Rios, Liu, & Bridgeman, 2014). Frequency distribution analysis revealed that there was an overall higher tendency to report high motivation regardless of course difficulty level.

Although the active teaching and course difficulty interaction was significant for learning motivation, this moderation was less effective at high course difficulty as evidenced by the negative interaction term coefficient and simple slopes depicted in Figure 4. It could be that at low course difficulty, active teaching was better able to facilitate acquired learning, experienced success, learning satisfaction, and subsequent desire for further success episodes which induced learning motivation. However, high course difficulty conditions may have diminished the potential for active teaching to induce learning motivation due to tasks that exceeded capability and the inability to experience positive outcomes.

**Implications and Limitations**

A contribution to a theoretical framework can either, confirm, extend, or present a model that demonstrates greater predictive power, or help improve the understanding of a phenomenon (Corley & Gioia, 2011). The results of this study offer a theoretical contribution worthy of consideration in future research on teaching and learning settings. First, the results confirm the tenets of Kolb’s experiential learning theory (Kolb & Kolb, 2005) in that classes with higher reported levels of concrete experience and (e.g., instructor guided in-class activities), reflective observation (e.g., class discussions), and active experimentation (e.g., repetitive exercises and quizzes) promote higher learning outcomes and learning motivation. Secondly, this study highlights the fact that the moderation effectiveness of active teaching on course difficulty appears to depend on whether one is considering objective outcomes such cognition or subjective/affective outcomes such as learning motivation. This study’s result suggest that the moderation of course difficulty was easier on course grade than learning motivation. Thirdly, a practical contribution is provided through the confirmation of a dual role of course difficulty - cognitive and motivational. Educators should attempt to increase learning motivation by emphasizing the importance and applicability of the learning material and by trying to link the material to students’ intrinsic motives.

Limitations to this study included that it was administered at one university setting with a predominately Black student sample which implies potential generalization issues to more heterogeneous populations. Another limitation may be attributed to potential bias from the use of the self-report method in measuring learning motivation. It is not uncommon for research subjects to avoid reporting shortcomings. Although these limitations suggest that results may not fully generalize to other academic settings or academic disciplines, results are consistent with the literature reviewed herein. In addition to addressing the limitations stated above, future research could utilize a controlled experiment utilizing tasks with at least three distinct levels of course difficulty. This could provide a better understanding of the role of course difficulty on determining learning motivation. Finally, future research should also attempt to identify other
factors that can be moderated by active teaching and identify any factors that might mediate the relationship between active teaching and learning outcomes.

**Conclusion**

Given the recent common occurrence of mediocre or substandard academic performance in colleges and universities, it is essential to identify and consider factors that might lessen these negative outcomes. Clearly, teachers should adopt and learn how to implement an active/experiential learning environment. If teachers are to effectively address course difficulty, they should provide previews and reviews, many worked examples, make students solve problems, and prepare structuring outlines and guides that provide focus and minimizes unnecessary information. In addition, if active teaching environments are to be more effective at dealing with both cognitive load and affective responses attributed to difficult coursework, some efficacy building efforts must be included in the instructional design (Gebka, 2014). Finally, administrators should provide support for training in active teaching.

**References**


AN INNOVATIVE MODEL TO TEACH IT BASED ON EMBODIED COGNITION AND SENSORY MARKETING

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ABSTRACT

This paper describes and implements an innovative model for teaching information technology (IT). The model creates metaphors for various IT topics using popular music videos. The theory of embodied cognition or grounded cognition argues that all aspects of cognition, including decision making, are shaped by aspects of the body. Various theories of neuroscience, the interdisciplinary study of the nervous system, are used to explain how the brain processes the information and multi-modal stimuli generated by our model. Our model can also be considered a form of sensory marketing, which is also based upon embodied cognition, theories of neuroscience and the cognitive significance of metaphors. The model was implemented at the secondary and university levels using both a formative and summative evaluation process. The survey results support the theoretical arguments supplied by the theories of embodied cognition and neuroscience.

Introduction

In this paper, we propose an innovative model that enhances the understanding of IT based on the theory of embodied cognition. The model is an extension of the one proposed by Rappaport et al. (2016) which was applied to the topic of robotics and automation. The theory of embodied or grounded cognition argues that all aspects of cognition, including decision making, are shaped by
aspects of the body. The physical aspects include the motor system and the perceptual system that are built into the brain and effect the body’s interaction with the environment (Rosch, Thompson & Varela, 1991). In social and cognitive psychology, research on embodied cognition encompasses issues such as social interaction and decision-making (Borghi & Cimatti, 2010). This research supports the embodied cognition view that the motor system influences cognition, just as the mind influences bodily actions. Furthermore, Edelman (2004) and Damasio (1999) have outlined the connection between the body, individual structures in the brain and aspects of the mind such as consciousness, emotion, self-awareness and will.

The model is presented by a multi-media PowerPoint presentation in which metaphors link various topics of IT with popular music videos. Sensory stimuli from these videos including the lyrics of the songs, still images, dance, other movements of humans and inanimate objects, facial expressions and the general motion pictures actualize the process of embodied cognition. For example, dance routines can represent different forms of data transmission or networking. Because the music can instill an emotional aspect to a presentation, our model is particularly innovative; IT topics are not normally associated with emotions. An important aspect of the model is its ability to enhance the imagination of the participants.

The model has been implemented for junior and senior high school students as well as for introductory computer science classes at the university level. Initially, a formative evaluation process was conducted using a focus group at one of the Philadelphia charter high schools. An improved framework for the PowerPoint presentation was developed based upon the feedback from the focus group and then implemented at additional sites. A summative evaluation was done
using the impacts frameworks for informal science projects developed for the National Science Foundation.

Our model is based to a great extent upon the role of sensory experiences in judgement and decision making which has been of interest to researchers in recent years in marketing and psychology. In marketing, the scattered research on the role of the senses in consumer behavior has been brought together under the name “sensory marketing” (Krishna, 2012, 2014) and is based in large part on the theory of embodied or grounded cognition. The stimuli from the videos in our presentation create sensory experiences for the participants with potential to alter their judgement and behavior in positive ways towards the study of IT topics. The participants play the role of the “consumers” in our model.

Many theories of neuroscience, the interdisciplinary study of the brain, support the idea of embodied cognition. Neuroscience also reveals that effective decision making is not possible without the motivation and meaning provided by emotional input. For example, Antonio Damasio had a patient who underwent neurosurgery for a tumor and lost a part of his brain connecting the frontal lobes, that control reason, with the emotions. Rather than this making the patient more rational, he became paralyzed by every decision in life. In other words, feelings provide an essential component of human decisions (Jarrett, 2014; Seth, 2014). Our paper shows how many theories of neuroscience support our model.

For many consumer researchers, embodied cognition is intimately connected with the idea that sensory experience in one domain can influence cognition, emotion, and behavior in a different domain in ways that follow familiar metaphors, for example, the association of physical and social warmth in everyday language speaks of a “warm” person or a “cold” shoulder. Metaphors play a
critical role in our model as they link the sensory experiences from the videos to information on various IT topics, for example, the beat of a drum can be linked to concepts of a database which is typically symbolized by a “drum” symbol in the IT literature, and can be viewed as radiating waves of information throughout an organization’s environment.

Cognitive linguists Lakoff and Johnson believe that all or nearly all thought are essentially metaphorical and provide a philosophical basis for the concept of embodied cognition. Their earlier work *Metaphors We Live By* (1980) had an extraordinary influence in emphasizing the role of the body in thought, language and knowledge, a subject now at the center of neuroscience, cognitive science, linguistics and philosophy. Twenty years later they reunited and wrote *Philosophy in the Flesh* (1999) which is a bold incursion of cognitive science and metaphor theory into the trenches of traditional philosophy with fascinating consequences for scientific and intellectual inquiry.

Another component of our model considers various contextual factors such as race, ethnicity, culture, and the vehicles for socialization used by our youth. Music videos are generally targeted to the youth and contain many social and cultural manifestations of their real life experiences. Integrating these into the educational process allows students to reflect on their own experiences and direct their own learning based upon these experiences. Our model also has the potential to engage students with diverse cultural backgrounds and particular demographic groups, including African Americans, Latinos or females. In addition, our model can be used to integrate students with diverse cultural backgrounds within the same learning environment. For example, hip-hop/rap music is generally enjoyed by youth from all socio-economic and ethnic classes. In
particular, dance metaphors can enhance the educational process by a process of creative constructions and reconstructions of self-identities (Hanna, 2015).

Figure 1 represents the conceptual framework of our model.
An Interactive Monte-Carlo Simulation Tool to Teach Simulation and VBA
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Abstract
This paper presents an author-developed interactive tool that can be used to help students develop and run spreadsheet-based Monte-Carlo Simulation models, with output statistics automatically calculated. The software also provides the instructor the ability to help students learn some aspects of Visual Basic for Applications (VBA), Microsoft’s programming language shipping with most of the products in the Office suite of applications. It requires no special installation, and runs on both Windows and OS X versions of Excel. The bar to getting started, and having students use the tool productively, is much lower than with commercial packages. It provides some unique advantages over both commercial-product and native Excel simulation approaches.

Introduction
As Business Analytics is more recognized in industry as providing value to organizations, interest in academic programs appears to be increasing significantly as well. At the author’s institution, the number of undergraduate business students specializing in information systems and/or business analytics (in a combined program) has increased dramatically over the past several years. Coupled with this is an increase in the number of specialized master’s programs in analytics and related areas.

The increased demand creates opportunities as well as challenges. With curriculum space (supply) not always as large as the need for courses in analytics-related areas (demand), some courses are called upon to cover additional topics, or to combine topics in order make more efficient use of time in courses.

This paper presents an author-developed interactive tool that can be used to help students develop and run spreadsheet-based Monte-Carlo Simulation models, with output statistics automatically calculated. The software also provides the instructor the ability to help students learn some aspects of Visual Basic for Applications (VBA), Microsoft’s programming language shipping with most of the products in the Office suite of applications. It requires no special installation, and runs on both Windows and OS X versions of Excel. The bar to getting started, and having students use the tool productively, is much lower than with commercial packages.

Sometimes, depending on the course and/or the students, instructors choose to teach simulation without using commercial add-ins (e.g., Crystal Ball, Analytic Solver Platform, @Risk), or at least have students learn to conduct simulations using only native Excel functionality. In addition, the course may have broader goals, including exposing students to programming. While most business students will not become computer programmers, there is value in learning something about programming, as graduates will likely encounter work with advanced spreadsheet models, web-based scripting, and possibly application programming interfaces (API’s). At a minimum, graduates of information systems and/or
business analytics programs will work with people using these tools, and a basic understanding is important. It is such a course for which the tool discussed in the paper was developed.

This paper first briefly reviews relevant literature. The overview the model and illustration of its functionality is then presented. Implementation of the model follows, along with teaching applications and observations, comparisons to other tools, and conclusions.

**Literature Review**


Simulation has also been found to be an effective methodology for teaching other topics. For example, Meilczarek & Zabawa (2011) explain how they use Monte-Carlo simulation to help teach a variety of other Management Science topics. And, Tsai & Wardell (2006) use a VBA-based tool to teach statistics concepts. Doane (2004) makes an argument for using simulation to teach about probability distributions. Similarly, Haney (2015) and Weltman (2015) teach students sampling distribution concepts using Monte-Carlo simulation. Valle & Nordell (2013) teach about forecast uncertainty using Monte-Carlo simulation. In the quality control arena, Balakrishnan (2005) presents a VBA-based tool for teaching statistical process control and process management. And Pappas et al. (1982) discuss a tool designed to teach statistical quality control that turns out to be effective in teaching simulation.


The contribution discussed in this paper is that the interactive simulation tool, while primarily designed to help students learn Monte-Carlo simulation, is also a suitable platform from which to begin teaching VBA as well. As classroom time is a scarce resource, it is important to leverage teaching resources. The tool described in this paper is highly visual, promotes understanding of what is going on in a simulation, and also provides the opportunity to delve deeper into how the tool functions.

**Model Overview and Illustration of Functionality**

This section presents the overall design philosophy of the interactive tool (model), provides an overview of the logic, discusses how VBA is used to make the tool interactive, and presents an example of the tool’s use.

The interactive tool is intended to be as easy to use as possible, to a) allow the instructor and student to focus on the important aspects of simulation, and b) provide the user with visualizations and statistics.
automatically and interactively, as the simulation runs. The tool is a single Excel workbook, containing several VBA macros, and so saved as an XLSM-extension file. The only guidance needed for the user to open the tool is to enable macros to run. No add-in installation or license code is required.

Figure 1 shows the overall structure of the single-worksheet file. At the top-left INPUT section, the user enters a random variable function (e.g., =RAND(), or any formula directly or indirectly involving randomness). The user can also click the Instructions button for detailed instructions on the usage of the tool; the input cell has a detailed comment about what can be entered into it. The CONTROL section allows the user to run one or more trials, with the user specifying how many trials to run. It also allows the user to reset the simulation (wiping out all trials information), and to toggle screen updating on or off. Turning off screen updating allows the simulation to run more quickly. The STATISTICS section shows many descriptive statistics. The QUERY section allows the user to query a specific cumulative probability value, by entering either the cumulative probability, or the value of the output measure. The VISUALIZATIONS section shows a frequency histogram and a cumulative distribution chart. The number of bins of the frequency histogram can be changed easily using a slider control. Below the visualizations is the FREQUENCY section, showing the details of the frequencies. To the right, usually out of the user’s sight, but available if desired, is the result from each trial (TRIALS section).

Basic Usage

A screen shot of the tool is in Figure 2. This shows the tool after 100 trials have been run, with Cell B3 having the formula =RAND(). This is essentially the most basic form of the tool’s use, replicating the standard Excel function to generate uniformly distributed random numbers between 0 and 1. Because the tool is interactive, however, while the trials are being generated, the results update (as long as Screen Updating is set to TRUE). Therefore, the user can watch the charts being created on the fly. The user can also request an additional 100 (or any number they choose) trials, without wiping out the original 100. In effect the simulation pauses after running the number of trials the user specifies. This can be an effective learning tool in terms of how more trials affects the results (statistics, output distribution, confidence intervals, etc.) of a simulation. For example, Figure 3a shows the charts after 900 additional trials, for a total of 1000. Obviously, the histogram and cumulative charts are smoother. The user can also change the number of bins in the histogram based on the same trials, which can be beneficial in the display of results (Figure 3b).

Used in this way, the tool can help one understand the effects of sample size. By inserting different functions into Cell B3, the user can learn and/or confirm knowledge about various probability distributions as well. Example formulas for Cell B3 are many, but include

- =RAND()+RAND(). Asking students what they believe the shape of this distribution will be brings out their intuition (many believing it will be uniform between 0 and 2), and why we need to test our intuition. One can continue the sum with additional RAND() functions and begin to gain intuition for one of the results of the Central Limit Theorem.
- =NORM.INV(mean, std.dev). The most recognized distribution by almost everyone, and in terms of simulation, a good example to use to illustrate that we may need many trials from a simulation to get a representative picture of what may happen in real life.
- =RANDBETWEEN(1,6). Simulating the roll of a die. This can be a good example to emphasize the point that the average of the trials from a simulation (3.5 in this case) may be a value that has
zero probability of occurring on any individual trial. Often students have a tendency to put more emphasis on an average result than on the distribution of outcomes. Relating this to business situations emphasizes the importance of quantifying and picturing the risk profile of a situation.

**Example**

Going further, and really to the initial motivation for the tool, is to set the formula in Cell B3 to something of practical importance. That is, set the formula to the 1-trial output value of a simulation model. Because a cell’s formula can reference a cell on a different workbook, the tool makes it very easy to run a simulation. Figure 4 shows a simple 5-year investment simulation, stored in a separate workbook. The starting balance is $1000, and every year there is a randomly-generated return according to a normal distribution. The Excel function NORM.INV is used to generate the returns each year. The 1-trial output is in Cell F27.

In the simulation tool, Cell B3 is set to point at Cell F27 in the investment example file, using the formula =Investment-Example-5year.xlsx!Model!$F$27. Now, all the user needs to do is Clear History (otherwise the new trials will be appended to the old, which may have been from a different model), and run as many trials as they wish. Figure 5 shows the screen shot after 1000 trials were run of the investment example. As expected in this case, the mean of the simulation model is essentially equal to the mean from the deterministic model. However, now the user has access to a wealth of information relating to the risk profile of the investment, in addition to insight into the shape of the output distribution, and a straightforward way to learn about the cumulative distribution function.

The simulation results also include numerous descriptive statistics, calculation of the confidence interval for the mean (for a user-specified significance level), and cumulative distribution lookup values. In Figure 5, the user has entered 0.05 for the percentile, and the tool has returned $799.36, indicating a 0.05 probability of ending the 5-year period with this amount or less (i.e., the 5% Value at Risk). The user has also entered a value of $1000, with the tool returning 0.136, indicating this probability of ending the 5-year period with $1000 or less (i.e., incurring a loss after 5 years of investing with this strategy).

This tool is very effective in helping students see enough of what a simulation is doing, without overwhelming them with either significant mechanics in Excel to run the simulation using a Data Table, followed by ad-hoc calculation of summary statistics and charts. At the same time, it shows them enough for them to understand what is going on behind the scenes. This is something that high-end commercial simulation add-ins tend to shield the user from, which is not a bad thing, but may not be ideal for a student first learning about simulation.

**Included Random Number Generators**

Some of the interactive functionality of the tool is enabled by VBA, which is discussed in more detail in the Model Design section. In addition to the VBA code for that purpose, the tool includes several random number generators (RNG’s), as listed here (each have applicable calling parameters):

- RndUniform: Continuous uniform
- RndDUniform: Discrete (integer) uniform
- RndNormal: Normal
- RndBinomial: Binomial
- RndExponential: Exponential
• RndTriangular: Triangular
• RndPoisson: Poisson
• RndDiscrete: Discrete; input is range of values and range of frequencies or probabilities
• RndReSample: Input is range of values; one is chosen at random; works on numeric and non-numeric ranges.
• RndContEmp: Input is value range and associated cumulative probabilities. Converted to piecewise continuous distribution.
• RndGeom: Geometric
• RndNegBinom: Negative Binomial

This puts the tool in between Excel-only simulation, and simulation using a powerful commercial add-in. Use of these RNG’s is completely optional; one can still write native Excel formulas to generate the random values, as was done in the example previously presented. However, some distributions are more difficult to write, at least into a single cell. Therefore, these are provided for ease of use. Note that if a user does choose to use these functions in their model, the simulation tool file and the model file are more tightly linked than otherwise. Alternately, one can unprotect the simulation tool file, and build the simulation model right in a copy of that file, on a separate worksheet.

Even with this functionality, the tool needs no installation, and works with Excel on both Windows and OS X platforms. The commercial tools tend to be Windows-only, and some students always seem to struggle with their installation, or company policies restrict installation of new software.

Model Implementation

Being an Excel/VBA model, one either consciously or subconsciously decides how much of a role native Excel has in the look/feel/operation of a tool, and how much of a role VBA has. For this tool, the author chose a design that is heavy on the native Excel portion, building in the vast majority of functionality with native Excel, and utilizing VBA to automate specific aspects of the tool. Every software project is different, and this is not necessarily the best approach for all. However, with a design goal of a tool that was both easy to use, but also helped the user learn about the details of simulation, the author believes this approach is the most appropriate here. This section explains the native Excel design, and provides an overview of the VBA usage to make the tool operational.

Native Excel Design

Referring to Figures 1 and 2, the native Excel portion is essentially all the sections except the CONTROL section. The TRIALS section will contain the results from each of the trials. The range of values from the trials is named Results_1. The STATISTICS and QUERY sections are built using standard Excel formulas, using the Results_1 as the data range. In the FREQUENCY section, the Cumulative Percentiles are also computed using standard Excel functions, namely PERCENTILE. The Frequency Distribution (histogram) is somewhat more complex, as the user can enter the number of bins they wish (a slider was implemented for ease of use for this). Based on the number of bins, the bin size is computed based on the maximum and minimum values from the simulation, and the number of bins. This bin size is then used in the frequency distribution calculations for the upper bound on each bin. The FREQUENCY array function is used to find the frequencies in each bin.
The Cumulative Distribution chart is a standard scatter chart of the cumulative distribution calculations. The histogram is a column chart that shows just the number of values from the frequency distribution calculations that the user has specified in the number of bins. This chart is therefore dynamic, and requires somewhat more setup. This chart uses the Excel named ranges BinRange and PercentRange. Both of these are dynamic ranges, defined using Excel’s OFFSET function. As the user changes the number of bins, the definition of these ranges automatically updates, so that what is displayed in the histogram is exactly what the user has requested. In addition, the title of this chart is dynamic in the sense that it contains the number of trials.

The worksheet is protected, and the VBA code changes this value when needed in order to make changes to the worksheet. In addition, if the user wishes to make changes to the worksheet (recommended only on a copy of the file), they can unprotect the sheet.

VBA Functionality

All of the above is done with native Excel. However, VBA is needed in order to provide control over the calculation of the trials, resetting of the trial data, and toggling whether the screen is updated during the simulation. The amount of actual VBA code is quite small, but essential to these operations. Below is a list of the procedures, and a short description of their functions:

- **Sub workbook_open().** Event-based; runs when the workbook opens. Calls the Initialization routine.
- **Sub Initialization().** Initializes certain settings so that each time the tool is opened, the user has a similar interface.
- **Sub ToggleInstructions().** Toggles whether the instructions are shown or not. The instructions are stored as a comment in Cell A1. Mapped to a button on the interface.
- **Sub ClearHistory().** Clears any trials data; that is, any results in the Results_1 named range. Mapped to a button on the interface.
- **Sub OneTrial().** Runs one trial of the simulation. Forces a calculation of Cell B3 (and prececessors/dependents), and stores the result of that trial in the range defined by the Result_1 array. Logic is needed to put the result in the next available slot in this array. Mapped to a button on the interface.
- **Sub many_trials().** Runs the number of trials as specified by the user in the applicable cell in the interface. Mapped to a button on the interface.
- **Sub ToggleScreeenUpdate().** Turns on/off screen updating. Mapped to a button on the interface.

The OneTrial routine is essentially the crux off the tool from the VBA standpoint. It actually tells Cell B3 (which has the range name “Output”) to calculate. It does this through the VBA statement Range(“Output”).Calculate. If B3 contains a simple =RAND() function or some other random number generator not referencing any cells, it re-generates itself. If it directly or indirectly references other cells (for example, on a separate model workbook), it cascades the recalculation to that cell and any of that cell’s predecessors. In addition, because B3 changes, any of its dependent cells re-calculate (e.g., the statistics, frequencies, etc.).

Besides these VBA routines, the RNG functions listed earlier are written as VBA functions.
Teaching Scenarios and Observations

This simulation tool can be used in a number of different ways, from a quick demonstration of simulation, say in an Operations Management, Marketing, or Finance class, to usage in a Business Analytics class that covers simulation in more depth as well as VBA. It can be used as the only demonstration of how to do Monte-Carlo simulation in Excel, along with pure native Excel (e.g., Data Tables), and/or with a full-scale commercial tool (e.g., Analytic Solver Platform, Crystal Ball, @Risk). The author uses it in a Business Analytics course that covers both simulation as well as some aspects of VBA. While students will by no means be expert VBA programmers, they will at least know some of its capabilities and potential uses. Students seem to enjoy being able to add quick and easy functionality to their models through VBA. This tool shows how just a little bit of VBA code can add considerable additional functionality to a model.

The tool can also be used at a more fundamental level, to help teach about random variables and probability distributions, as well as descriptive statistics. With the ability to quickly generate values from any distribution one can code into a workbook cell (using the functions in the VBA code in the workbook itself, this list is larger), students can learn more intuitively and visually about various probability distributions.

Observations from students have been very positive. At a basic level, by seeing the results being generated one trial at a time, students seem to “get” the idea of simulation much more than, say, running 1000 trials of a simulation using a commercial tool, and even by setting up Excel to run a simulation using a Data Table. The immediacy of seeing the result of 1 trial of the model, and then having that translated into charts and statistics, makes the connections about what Monte-Carlo simulation clearer to students. This insight was the key motivator for the development of this tool.

An unexpected observation was that students can take this tool with them after the course is over, without any licensing restrictions. This is typically not the case for commercial tools. MBA students often want to continue using simulation after the course is over, and they may not be able to convince their firms to purchase a commercial license. With this tool, however, they can at least demonstrate what simulation can do for their firm, to bolster their case for a more powerful tool.

VBA Instruction Possibilities

The rest of this section addresses how using the tool can allow the instructor to teach students some aspects of VBA. VBA is a full-scale programming language, with the additional capability of having access to the Microsoft Office object library. Therefore, no single example, or even a full course, will result in VBA experts. The author believes that learning VBA is a bit like learning native Excel. Once one has a basic foundation, one can learn for the most part incrementally, on an as-needed basis, after that point. One might consider a spiral of learning, where one needs to learn a little bit at the beginning, and then gradually learn more and more as time goes on.

Because VBA is a programming language, it has mechanisms for defining variables, loops, conditional logic, passing control, etc. But it also has access to much of the functionality of native Excel through the object library. Figure 6 displays different aspects of VBA in a chart, used to help explain different aspects of VBA to students. When this chart is used, it is emphasized that one does not need to learn everything
about any wedge initially, but just needs to know some basics, and then one can learn incrementally as
time goes on.

With the simulation tool, there are different aspects of VBA that can be addressed. One of the first
aspects that many people learn with VBA is recording a macro. One of the features of the simulation
tool is displaying the instructions (comment on Cell A1) or not. One can record a macro to display the
instructions, and a macro to not display them (i.e., show the comment, hide the comment). Then by
studying the VBA code, students can begin to learn the structure of VBA code (subs, statements, how
VBA references Excel objects, etc.).

Going further, an illustration of conditional logic, and looping, can be illustrated by studying (and
perhaps improving) the code for running one trial (Sub OneTrial, and Sub Many_Trials). These routines
also tap into Excel’s object model, especially the Range object, which is used in this case to put the
numerical output of a trial into the output section of the spreadsheet. Figure 7 shows the code for these
two routines.

In the OneTrial routine, the following programming and VBA concepts are illustrated:

- Line 1/12. Declaration, and ending, of a subroutine.
- Line 2. Variable declarations, data types.
- Lines 3 & 4. Control over Excel. Specifically, using Excel’s object model to unprotect the sheet,
  and to calculate a specific cell on the sheet (which cascades to the calculation of other cells).
- Lines 5 & 6. Using pointer variables to know where to put the newly-created trial value.
- Lines 7-9. Conditional Logic (If...then...else). Need to consider the case that this is the first trial or
  not.
- Line 10. Actually putting the value of the new trial into the output range.
- Line 11. Cleaning up after oneself; reprotect the sheet, as it was when entering the subroutine.

In the Many_Trials routine, many similar concepts are illustrated. In addition, a simple loop is done in
lines 16-18 to run the trials. Importantly, within this loop one calls the OneTrial subroutine. This concept
of programming is very important for students to learn, as with it one promotes the concept of reusable
code, and the idea of developing small segments of code that can be tested.

While the code is not shown here, the Workbook_Open routine is also important. This routine runs
automatically whenever the workbook is open (and once the user gives permission to enable macros).
This can be a nice way to introduce the concept of event-based procedures. If the course spends more
time on programming, this is an easy first example of such.

In a given course one might not teach VBA explicitly. But it does not take long to illustrate the VBA code
and show students how to view it. One can also use this simulation tool as a the basis for either lab-
based exercises or homework to develop improvements and/or new functionality to the code.

**Comparison to Other Available Tools**

The simulation tool discussed in this paper provides a useful way for students to learn about Monte-
Carlo simulation, experiment and play with it, and generate useful results. It is also an entry point for
learning about VBA, and the tool can be used either as a launching point for learning about VBA, or at
some point in the teaching/learning process to have students evaluate and/or improve the code.
The tool here is by no means a complete Monte-Carlo simulation solution. The commercial products are very well executed; e.g., Analytic Solver Platform, @Risk, and Crystal Ball. There are also a number of lower-cost options, e.g., RiskSim. These products provide much more functionality than the simulation tool discussed here with respect to tracking multiple output cells, more built-in probability distributions, correlated random variables, and in some cases, stochastic optimization.

The intent of this tool is not to replace any of these products, but to complement. By providing a tool that interactively shows users the results of the simulation as they are generated (raw results, summary statistics, frequency distributions, and cumulative percentiles), the user can develop a better understanding (and trust) of what simulation can do for them in a decision-making situation.

Conclusion

This paper has presented an interactive Monte-Carlo simulation tool that allows the users to see the results of their simulation as they are generated. It requires no installation; it is a standard macro-enabled Excel file (XLSM). Unlike commercial tools, it contains no license expiration. In addition, it provides an avenue in which students can begin to learn programming, using VBA. While most business majors will not become programmers, it is the author’s opinion that students in technology-oriented business disciplines should have at least an introduction to logic of programming in some language. This tool provides a flexible way to provide that introduction at a level of the instructor’s choosing.

References


Figure 1. Overall Layout of Interactive Simulation Tool

INPUT and Instructions

CONTROL (inputs and buttons to run VBA code)

STATISTICS (Descriptive Statistics based on simulation results)

QUERY (user input, corresponding simulation results)

VISUALIZATIONS (Frequency Histogram Chart and Cumulative Distribution Graph)

FREQUENCY (Frequency Counts and Cumulative Percentiles)

TRIALS (results from each simulation trial; visible to user if they scroll to the right; otherwise out of sight)
Figure 2. Screen Shot of Tool; 100 trials of RAND()

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
<th>H</th>
<th>I</th>
<th>J</th>
<th>K</th>
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<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Instructions: On/Off</td>
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<td></td>
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<td>Plan One Trial</td>
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<td></td>
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</tr>
<tr>
<td>10</td>
<td>100 trials</td>
<td>~ end of trials</td>
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### Simulation Results for 100 Trials

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<td>2</td>
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</tr>
<tr>
<td>3</td>
<td>0.30</td>
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<tr>
<td>4</td>
<td>0.40</td>
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<td>5</td>
<td>0.50</td>
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<td>6</td>
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<td>8</td>
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<td>9</td>
<td>0.90</td>
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<tr>
<td>11</td>
<td>1.00</td>
</tr>
<tr>
<td>12</td>
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<td>13</td>
<td>1.20</td>
</tr>
<tr>
<td>14</td>
<td>1.30</td>
</tr>
<tr>
<td>15</td>
<td>1.40</td>
</tr>
</tbody>
</table>

Northeast Decision Sciences Institute 2017 Annual Conference
Figure 3(a). Histogram and Cumulative Charts after 1000 trials

Figure 3(b). Same Trials, But With Histogram Showing More Bins
### Figure 4. Investment Simulation Example

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>E</th>
<th>F</th>
<th>G</th>
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<tr>
<td>2</td>
<td>Compare Deterministic Analysis with Simulation Analysis</td>
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</tr>
<tr>
<td>4</td>
<td>Investment</td>
<td>$1,000</td>
<td>(user can change this)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Term (years)</td>
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<td>(information only; don't change this without adding rows to calculations)</td>
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<tr>
<td>6</td>
<td>Mean Return (annual)</td>
<td>8.0%</td>
<td>(user can change this)</td>
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<td></td>
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</tr>
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<td>Std.Dev. Return (annual)</td>
<td>15.0%</td>
<td>(user can change this)</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<td></td>
<td></td>
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</tr>
<tr>
<td>9</td>
<td>Ending Balances</td>
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</tr>
<tr>
<td>10</td>
<td>Deterministic Model</td>
<td>$1,469</td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>11</td>
<td>Simulation Model (one trial)</td>
<td>$1,650</td>
<td></td>
<td></td>
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<td></td>
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</tr>
<tr>
<td>13</td>
<td>Deterministic Model (no uncertainty; uses the mean return each year)</td>
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<td></td>
<td></td>
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<tr>
<td>14</td>
<td>Year</td>
<td>BegBal</td>
<td>Return%</td>
<td>Return$</td>
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<td>$80</td>
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<td>18</td>
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<tr>
<td>21</td>
<td>Simulation Model (one trial; generate annual returns from a Normal Distribution)</td>
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<tr>
<td>22</td>
<td>Year</td>
<td>BegBal</td>
<td>Return%</td>
<td>Return$</td>
<td>EndBal</td>
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<td>($23)</td>
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<td>24</td>
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<td>$1,307</td>
<td>54.6%</td>
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<td>($201)</td>
<td>$1,819</td>
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<td>5</td>
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<td>-9.3%</td>
<td>($169)</td>
<td>$1,650</td>
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</table>

D23: =NORM.INV(RAND(),B$6,B$7) (copied to D27)
Figure 5. Simulation Tool, Showing Investment Example Results

### Summary Statistics

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<th>Value at a Given Percentile</th>
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<td>1489.75</td>
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<td>StdDev</td>
<td>479.17</td>
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<td>Percentile Value</td>
<td>60%</td>
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<td>Max</td>
<td>4884.02</td>
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<td>Median</td>
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<td>UCL: Mean</td>
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</table>

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### Frequency Distribution

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<td>2.0%</td>
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<td>5.9%</td>
<td>8.4%</td>
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Figure 6. Elements of Visual Basic for Applications: Learning as a Spiral from the Center Outwards
Figure 7. OneTrial and ManyTrials VBA Code

1 Sub OneTrial()
2    Dim NextRow, Col As Long
3    Worksheets("Sim Inc").Unprotect
4    Range("Output").Calculate
5    NextRow = Range("HistoryHeader").End(xlDown).End(xlDown).End(xlUp).Row + 1
6    Col = Range("HistoryHeader").Column
7    If (NextRow = Range("HistoryHeader").Row + 1) Then
8        Cells(NextRow, Col) = 1
9    Else
10       Cells(NextRow, Col) = Cells(NextRow - 1, Col) + 1
11    End If
12    Cells(NextRow, Col + 1) = Range("Output")
13    Worksheets("Sim Inc").Protect
14 End Sub

15 Sub Many_Trials()
16    Dim i, n As Long
17    n = Range("num_trials").Value
18    For i = 1 To n
19        Call OneTrial
20    Next i
21 End Sub
Robin B. Saunders
Chair Communications and Information Management Programs
Bay Path University

Title: Animate to Educate

Abstract
Walt Disney said “Animation offers a Medium of Storytelling which can bring Pleasure & Information to People of ALL ages.”

Recent developments in computer technology provide exciting, innovative ways of representing and interacting with information, bringing new perspectives on learning with multimedia.

Entertainment is a form of activity that holds the attention and interest of an audience, or gives pleasure and delight. Education can be entertaining.

Entertainment is a primary form of using the animation. At first, it was to be used in movies, cartoons or short videos. Animation is used to represent the things, which don’t exist in the real life and bring some magic and fiction into the academic setting. Educational animations are the animations created for a purpose of making the learning more interactive, interesting, and magical.

Animation has revitalized the learning environment in many ways by presenting innovative methods to convey topics and concepts, and these are continually evolving.

One of the greatest benefits of animation is that it is exceptionally flexible, versatile, and does not restrict imagination.

The multi-sensory aspect of animation also makes it appealing to a broad range of learning types. Almost all gaps in teaching could be closed with this captivating tool. Well-designed, effectively implemented animated videos that are supported by other teaching tools have great potential to motivate and enhance learning potential for students across the board.

Animation is being used to teach in ways that were not previously possible, and its potential continues to develop. There is no age barrier for the use of animated video.
Community Projects: How to Make a Global Impact

Minoo Tehrani, Alexander Murphy, Alessandro Millor
Roger Williams University

Involvement in projects that provide service to the communities has become a graduation requirement in more and more universities. The focus of these community projects is to encourage students to give back to the surrounding communities by volunteering their time and getting involved in actions that can cover a variety of activities, such as serving in a soup kitchen, cleaning the garbage from a beach, and providing tax services to clients among others.

This study describes a community project that goes beyond the surrounding communities and elevates the volunteer services provided by students to a level with the potential of global impacts. Getting our students involved in community projects with causes that go beyond the surrounding borders have tremendous potentials to instigate a deep sense of social responsibility that can be carried throughout their lives.

The community project under discussion was started by students at Roger Williams University and is entitled “Roger for Refugees.” The study discusses how this community project has become a global community project, it explains its vision, its goals and objectives, and its accomplishments. The study explains how this community project has succeeded in uniting several groups not only on campus, but also in bringing groups and people of different focus together from across the geographic borders.

**Abstract:**

Today’s rapidly changing global and technological marketplaces demand flexibility and innovation. Responding to these challenges, the contemporary leadership literature encourages the integration of emotional intelligence with rational analysis as a way to strengthen flexibility, creativity, and collaboration. While leadership, strategic marketing, and management training programs offer education about systems thinking -- as an aid to clarify complexity and offer insight into interconnections and problem solving -- fewer systems models address both rational and irrational influences on outcomes. Yet, decision-making processes are influenced by personal motivations, and new discoveries emerge from the ground of intuition. This is as true for marketing, product development, and management as it is for science and art.

Can intuition be strengthened? This session/paper explores the cultivation of awareness, emotional intelligence, and intuition through a new educational model. Grounded in social psychology, existential analysis, and systems theory, “Intuitive Systems Thinking” brings together systems analysis with the intuitive capacity to “listen” for “stories” behind system maps, interconnection points, and friction. This capacity is cultivated through a methodical self-awareness process that systematically fleshes out and illuminates roots of inner assumptions and resistance, offering the means to strengthen courage, creativity, and the vision afforded by a systems view.

**Key Words:**

Innovative Education, Integrative Models, Systems Thinking, Intuition

**Disciplinary Foundations & Topics:**

Systems Thinking, Engaged Learning, Applied Ethics, Leadership Development, Management/Marketing Education, Emotional Intelligence, Collaborative Intelligence, Authentic Leadership, Toxic Leadership, Extraordinary Leadership
Designing a Master of Science in Business Analytics

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Abstract

This presentation will review the process of creating an online master’s program in business analytics that provides an integrated, practical, and business-focused problem-solving approach to analytics. The program was designed to provide students with the required analytical skills, tools, and techniques for understanding data sets, both large and small, from sources internal and external to an organization.

This master in business analytics differentiates itself in many ways from offerings at other schools. It has been designed for business decision makers at all levels of an organization, and places an emphasis on the use and interpretation of data, not on programming or mathematics. The program also emphasizes the use of visualization as part of the data analysis process and as a communications tool for supporting decisions. The degree allows some course flexibility in terms of a business track focus, and each course is being constructed with a high percentage of interactive and innovative content specifically aimed to foster online leaning. An overview of the program curriculum and courses will be provided, as well as the reasons behind the choices that were made.

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Developing and Delivering an Online, Synchronous, Data Analytics with Excel Course

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Introduction
In this paper, I describe the design and implementation of a course covering the basics of data analytics using Excel, delivered synchronously to a cohort of working professionals. The following topics are discussed: general course philosophies and the principles upon which they are based, considerations for selecting a synchronous delivery software platform, the relative advantages and disadvantages of teaching synchronously online vs. asynchronously online and vs. traditional face-to-face teaching, and practical guidance for teaching any quantitatively oriented course in synchronous online mode.

This work may be viewed as a typical case study; while some elements were peculiar to the particular instance being described, most have broader relevance.

Online Learning: Asynchronous and Synchronous Approaches
The increasing use of online education in higher education has been a clear trend over recent years. A 2015 survey indicated that in the United States more than one in four students (28%) took at least one distance education course (Babson Survey Research Group 2015). Online classes may be broadly classified as either asynchronous or synchronous. Good characterizations of each are provided by Haslam (n.d.):

Asynchronous
- Asynchronous learning allows you to take online courses on your own schedule.
- Instructors provide materials, lectures, tests, and assignments that can be accessed at any time.
- Students may be given a time frame – usually a one-week window – during which they need to connect at least once or twice.
- Overall students are free to contribute whenever they choose.

Synchronous
- Synchronous online classes are those that require students and instructors to be online at the same time.
- Lectures, discussions, and presentations occur at a specific hour.
- All students must be online at that specific hour in order to participate.

Literature
Means et al. (2013) note that research in the field has indicated no significant difference in learning outcomes between traditional classroom environments and online settings. They conducted a meta-analysis that included studies contrasting learning outcomes for online learning settings with those of
traditional face-to-face instruction. Their findings indicate that “on average, students in online learning conditions performed modestly [but not statistically significantly] better than those receiving face-to-face instruction.”

A number of studies have contrasted asynchronous and synchronous education settings. Yamagata-Lynch (2014) examined optimizing the learning experiences for students in a blended online course relying on both synchronous and asynchronous technologies. She cites several studies (Chen & You, 2007; Mabrito, 2006; Hrastinski, 2010) that found that, “while engaged in synchronous learning when compared to asynchronous learning participants (a) find a stable means of communication, (b) tend to stay on task, (c) feel a larger sense of participation, and (d) tend to experience better task/course completion rates.”

The Course
The course is an Introduction to Data Analytics with Excel. It includes descriptive statistics, graphical representation of data, probability, brief coverage of inferential statistics, and regression from a traditional statistical perspective and a data analytics perspective. The data analytics approach to regression means that, instead of focusing on the inferential statistics components of the regression output, students split the data into training and test sets, apply the training model to the test data, and calculate and interpret error measures such as the root mean squared error, mean absolute deviation, and mean absolute percentage error.

Audience, Context and Rationale for Synchronous Delivery
This is the first course in a series of six courses that comprise a Data Analytics Certificate program. Each course runs seven weeks. Though proposed to, and designed for, a telecom company, the program is effectively a general data analytics curriculum designed at the executive education and MBA levels.

We had several meetings last year with representatives from the company and iteratively refined our proposal for the certificate program. Due to internal company issues unassociated us, the company put the idea on hold for a couple of months; when they ultimately responded that they wanted to move ahead with the program, we had only several weeks lead-time prior to the starting date of this course (the first in the sequence). Further, it was originally planned for the course to be delivered face-to-face (F2F) and on-site at the company, with a few students attending remotely. When the final go-ahead was given, we were informed that on-site delivery was not possible due to a change in company policies. Given their preferences and the short lead-time, a synchronous (as opposed to asynchronous) online format was selected.

The implication was that we had an extremely short window to create and deliver a course we had expected to teach in a traditional format. It also meant, given the delay in getting started and various company constraints affecting the timing of subsequent courses (e.g., annual education reimbursement for their employees), that there was no margin for error in the course delivery. That is, if something went wrong technologically with any given class session, there would be effectively no opportunity to make up the class. This was a lot of pressure.
Student, Instructor, and Institutional Backgrounds
The students were managers selected by the company (who satisfied our entrance requirements). A small group – some 12 students – with diverse backgrounds and varying degrees of strength in quantitative areas comprised the first cohort.

I’m an experienced teacher who regularly leverages technology in my classes. I’ve used statistical packages “live” in class (for example collecting data from students and analyzing that data on the fly) as early as 1985. I’ve been recording my lectures and posting them to Blackboard for years. I’m currently teaching two sections of a first-year undergraduate MIS course in flipped mode.

Seton Hall made an early commitment to instructional technology, implementing a mobile computing initiative for undergraduate students in 1996. It continues to encourage instructional technology use by its faculty.

Course Design
The design of the course relied on practical recommendations from two sources: Seven Principles for Good Practice in Undergraduate Education (Chickering and Gamson 1987) and the Guidelines for Assessment and Instruction in Statistics (GAISE College Report ASA Revision Committee 2016).

Seven Principles for Good Practice in Undergraduate Education
Now some 30 years old, but still relevant, the work itself and extensions are frequently referenced, and commonly included on university websites devoted to teaching and learning. These include, for example, sites at the University of Michigan (http://www.crit.umich.edu/gsis/p4_6) and the University of North Carolina, Charlotte (http://teaching.uncc.edu/learning-resources/articles-books/best-practice/education-philosophy/seven-principles).

The following is from the University of Michigan web page cited above:

“The Seven Principles for Good Practice in Undergraduate Education grew out of a review of 50 years of research on the way teachers teach and students learn (Chickering and Gamson, 1987, p. 1) and a conference that brought together a distinguished group of researchers and commentators on higher education. The primary goal of the Principles’ authors was to identify practices, policies, and institutional conditions that would result in a powerful and enduring undergraduate education (Sorcinelli, 1991, p. 13).

The seven principles suggest that, good practice in undergraduate education:

1) Encourages contacts between students and faculty.
2) Develops reciprocity and cooperation among students.
3) Uses active learning techniques.
4) Gives prompt feedback.
5) Emphasizes time on task.
6) Communicates high expectations.
7) Respects diverse talents and ways of learning.
Guidelines for Assessment and Instruction in Statistics Education (GAISE)
The GAISE report presents the recommendations of a group of statistics educators, funded by the American Statistical Association, for (as the title indicates) assessment and instruction in statistics education. In short, these recommendations are:

1. Teach statistical thinking.
   - Teach statistics as an investigative process of problem-solving and decision-making.
   - Give students experience with multivariable thinking.
2. Focus on conceptual understanding.
3. Integrate real data with a context and purpose.
4. Foster active learning.
5. Use technology to explore concepts and analyze data.
6. Use assessments to improve and evaluate student learning.

There is (not surprisingly) some overlap in the GAISE and Seven Principles guidelines. They have the advantage in my view that they are specific enough to be helpful, yet general enough to allow for variation in courses, instructor style, and delivery mechanism.

To varying degrees, I implemented all of these recommendations. However, the most relevant hurdle for an online synchronous course is the active learning component. A primary goal for me was to avoid as much as possible non-stop lecturing – think PowerPoint slides with a voiceover – for two hours at a clip. I address how these considerations influenced both what I did in the course, and my concerns about the software platform for the course.

Evaluating Platforms
Seton Hall has standardized on two possible platforms: Blackboard Collaborate and Skype for Business. I immediately turned to our department’s contact at the university’s Teaching, Learning and Technology Center for advice. He promptly eliminated Collaborate as a possibility as the video quality was poor, and the product was designed more for sharing PowerPoint presentations (though it’s possible to share a screen).

With his assistance, I evaluated Skype for Business but found a number of aspects problematic.
- There was no way to keep the participant (student) list active on the host (my) screen.
- There was no functionality for doing polling. In the spirit of interactivity, I thought this would be a crucial capability, serving much as “check questions” do in asynchronous courses.
- A lot of what I was teaching required using Excel. For some reason the display of Excel on student screens (where my cursor was, etc.) was difficult to see in Skype for Business.
- From my own experience and that of colleagues, Skype for Business demonstrated less than stellar audio capabilities. With this in mind, executive education courses delivered with Skype for Business also employed a separate phone bridge – not a deal killer, but another layer of complexity (and cost) that I preferred to avoid if possible.
- Generally, it seemed that Skype for Business was really built for conference calling, not so much for synchronous education.
I then evaluated WebEx in detail because it was a well-known product, the company to whom we were delivering the program had used it for other teaching initiatives, and the price was reasonable. (I would either have to get institutional support for this cost or pay for it myself.)

I reached out to WebEx and was able to get a fully functional test version to explore. In short, I found it had superior capabilities than Skype for Business in the areas I’ve outlined above. In addition, I found the user interface for WebEx was more intuitive, making it easier for me to learn the product and to use it “live.” Table 1 provides features to consider when selecting software for a synchronous setting.

I went to the administration with a good case for WebEx. They ultimately supported my proposal, because:

- I made a good case based on functionality of the competing products.
- As noted above, any technical failure would have had dramatic consequences – missing a session was not an option.
- The university saw this course and this certificate as an opening to ongoing executive education programs with this company so they wanted very much for things to go smoothly.
- The administrator in question knew me well and understood I wouldn’t make this kind of request without good reasons.

This meant of course that, with regard to using the software, I was on my own, with no institutional support. It also meant that I had to evaluate the contract carefully prior to signing it. Some issues: WebEx indicates “unlimited” meetings per month, but the contract “fine print” stipulates additional charges for more than 10,000 minutes of VoIP/phone per month, and for storing more 1GB of session recordings.

Suggestions for Preparing for and Running Asynchronous Classes

Naturally practice is essential before going live with a class. At least a couple of people will need to volunteer act as students for any practice sessions. I found it took two or three one-hour sessions to get up to speed with WebEx.

Some practical concerns while running a session include:

- Make sure nothing is on your computer screen you wouldn’t want students to see. (Alternatively don’t share the entire screen.)
- Close email and any other application that produce pop-ups on your screen.
- Unplug your phone so incoming calls/answering machine messages are avoided.
- Be sure background noises at your location are minimized. For example, if running a session from home, remind others there that the session is starting.
- Mute all participants to eliminate background noises at their end. Use chat for simple communication and feedback; unmute selectively when needed.
- I found it very helpful to have another computer on my desk (in addition to the one I was using to teach the session) and have it running as a participant so I could see what the students were seeing. Often I’d adjust the magnification of a spreadsheet, or move a window so students could see more clearly.
• Pause and check on students periodically. (Is the audio ok? Are there any questions?)

### Table 1: Software Selection Issues for Online Synchronous Learning

There might be no choice given university standards. If there is some choice, consider the following.

**Basic Features:**
- Screen sharing
- VoIP and/or phone bridge
- Chat Functionality
- Raising Hand
- Participant/Chat List Visibility
- Passing Control of Instructor’s Screen to a Student
- Passing Hosting to a Student
- Interactive Whiteboard
- Multi-Point Video
- Polling
- Recording
  - Proprietary or Standard Format?
  - Storage
- Anything else particular to your needs?

**Ease of Use**
- Intuitive for instructor and students?

**Possible Costs Related Issues:**
- Number of Participants
- Number of Hosts
- VoIP/Phone Bridge Minutes per Month
- Recording Storage
- Toll Free Dial-In Number

**Reliability**
- Up and Running 24/7
- Audio Quality
- Support

**Resolution:** Is the quality of the video on the student screens clear enough?

A Standard: When teaching executive education, is there an established platform (that is, one the company typically uses) that the students are already familiar with?
Implementing the Design Considerations
The GAISE and Seven Principles design considerations apply to all delivery modes. So, whether I’m teaching F2F or online, I try to use real world, engaging examples. For example, it’s easy to use a popular and relatively easy to understand example like MoneyBall as a case study/student exercise, or real and large datasets from Kaggle in an online course as in a F2F course. The more challenging part in my view, as I noted above, is the active learning component.

Mostly in this course I took advantage of the polling capability in WebEx, asked questions with the expectation that students reply via chat, and gave the students short problems to work on and report their results back to the class. I generally did not take advantage of allowing a student to take control of my computer, or passing hosting over to a student. I do intend on exploring these and other capabilities the next time around. (One reason I didn’t do more in this vein was that I fell a bit victim to “we have to get through this material and don’t have time to dawdle” syndrome. This being said, I do believe, and student feedback supports this, that the level of interactivity in the course was good.)

Relative Advantages/Disadvantages of Online Synchronous with Online Asynchronous and F2F
From my experience, a significant challenge in designing asynchronous online courses is in creating videos that have a “live” feel, when they’re created without students being present. A major advantage in teaching synchronously was that I generally felt like I was teaching before a class of students, and my energy level and enthusiasm were as per usual. Table 2 below provides a summary of my major observations of the relative advantages and disadvantages of synchronous online teaching vis–à–vis asynchronous and F2F.

<table>
<thead>
<tr>
<th>Table 2: Relative Advantages and Disadvantages of Synchronous Online Teaching Vis–À–Vis Asynchronous and F2F</th>
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</thead>
<tbody>
<tr>
<td>Advantage as Compared With Online Asynchronous</td>
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<tr>
<td>• Energy level of a F2F Class</td>
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<tr>
<td>• Students feel connected – to instructor and other students</td>
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<tr>
<td>• Immediacy of Question Answering</td>
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<tr>
<td>Advantage as Compared With Face-to-Face Class</td>
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<tr>
<td>• Location Independence</td>
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<tr>
<td>Disadvantage as Compared With Online Asynchronous</td>
</tr>
<tr>
<td>• As in a F2F class, students are expected to keep up with the “forward motion” of the session. (Can’t pause, rewind, take a break, etc. as in an asynchronous online class.)</td>
</tr>
<tr>
<td>• As in F2F class, requires student attendance and focus at that particular time.</td>
</tr>
<tr>
<td>• Each class session is a large block of time (two hours in my case). Might be particularly hard for working students at the end of a business day.</td>
</tr>
<tr>
<td>Disadvantage as Compared With F2F</td>
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<tr>
<td>• Lack of physical presence requires rethinking how to accommodate some pedagogical approaches (e.g., “watch this”, breaking up into discussion groups).</td>
</tr>
<tr>
<td>• Lack of physical presence may make personal connection more challenging.</td>
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Summary
This paper described the design and implementation of a synchronous online introduction to data analytics course delivered to post graduate working professionals. It is meant as constructive input to anyone considering implementing a quantitatively oriented online synchronous course.

The delivery modality in this instance was effectively a requirement, as opposed to a choice. The course ultimately went quite well as judged by formal and informal student feedback, test results, and the instructor’s judgment.

References


Educational Games in Operations Management, Logistics and Supply Chain Management: A Multi-stakeholders Perspective

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Educational games are increasingly used in classrooms to foster an active learning environment. In this study we present the perspectives of course instructors and students in higher-education institutions, as well as corporate employers on the values added by educational games in the fields of Operations Management (OM), Logistics, and Supply Chain Management (SCM). Our main goal is to understand what competencies are taught or enhanced by these educational games. The competency areas are adopted from APICS Distribution and Logistics Managers Competency Model and APICS Supply Chain Manager Competency Model. The frequently used simulation educational games worldwide and what competencies are taught/enhanced by the games are identified by a survey. The survey is sent to three target groups: instructors who have used business games in their classes; students who have played educational games; and employers who have relied on games to train their employees to work in the fields of OM, Logistics, and SCM. The geographic locations of the faculty respondents represent 18 countries. This paper presents the survey results, implications, and directions to interested audiences for future use of educational games.

Key words: Educational games, Business games, Business simulation games, Competences, Logistics, Supply Chain Management, Operations Management
This study focuses on the goals of the dual-degree program between EM Strasbourg Business School in France, the University of Adelaide and the University of Western Australia in Australia, the Corvinus University in Hungary, and Ca’ Foscari University in Italy. The program was launched in December 2013 and is called Scribe 21.

Employability is a key objective of this dual-degree project led by EM Strasbourg Business School. The program is designed to enhance participating students’ cross-cultural professional competences as well as business synergies between Europe and Australia in the 21st century. It is jointly funded by the European Commission’s Industrialised Countries Instrument – Education Cooperation Program (ICI-ECP) and the Australian government. According to students who have participated in the program, one of the major highlights is the three one-week intensive sessions held in different locations at regular intervals. These sessions enable them to better acquaint with one another and to expand their global knowledge networks.

When debriefing about their expatriation experience, students generally tend to refer to their enhanced adaptability, enthusing about how much they gained from studying overseas. According to them, living in a foreign country for a full academic year ‘opened up their minds’, ‘gave them new perspectives’ and ‘made them step out of their comfort zones’. In speaking in such terms, they feel that they uttered magic words allowing everyone, in particular recruiters, to readily identify with their profound overseas experiences. However, they fail to understand that the adaptability buzzword is devoid of meaning if it is not substantiated by concrete personal insights. They must thus be guided and assisted to better explain where their cross-cultural adaptability stems from and how they experience it in diverse ways. Failing to do so will prevent them from standing out from the growing numbers of students currently exposed to foreign cultures and cross-cultural interactions.

In order to enhance the cross-cultural experience of these students, we have designed a workshop offered at the final intensive session on the last year of the program. The purpose of the workshop is twofold: to raise students’ awareness of their acquired cross-cultural knowledge and to help them better communicate on their expatriation in job-hunting situations. On completion of the workshop, students are better equipped to more accurately comprehend and convey the outcomes and added value of their expatriation experiences.

This study explains how such a workshop is designed. The first phase of the workshop uses Martin J. Gannon’s cultural metaphors1 as well as other literature for students to deepen their own personal understanding of cultural specificities. The second phase of the workshop focuses on personal and collective storytelling with a special emphasis on metaphors as a component of stories designed to highlight cross-cultural knowledge, skills, attitudes and values.

**KEYWORDS**: Cross-cultural awareness – Employability – Metaphors – Storytelling

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Abstract: Integrating liberal arts studies into business education is nothing new, but integrating business education into liberal arts studies is not as common. Active, experiential learning pedagogies have been common in marketing curricula for decades, but they are not as widespread outside of business schools. This article describes an innovative, team-based experiential learning project which integrated students from across the University for a single live-case project. Team-taught by History and Marketing professors, students from both Arts & Sciences and Business Honors Programs worked together to understand a local client’s needs, examine competitive exemplars, identify relevant market segments, and propose promotional plans for the live client. Conclusions and factors to be considered when designing such integrative experiences are discussed.
Industry sponsored projects provide ample opportunities for students to learn, discover and apply what they have learned, and are considered one of the most effective experiential learning approaches in business education. At Worcester Polytechnic Institute’s (WPI) Foisie Business School, such projects sponsored by business enterprises and not-for-profit organizations are integrated into both undergraduate and MBA curricula. At the undergraduate senior level, all students must complete a team-based project called the Major Qualifying Project (MQP) in their major field of study. Each project focuses on the synthesis of all previous study to solve a problem or perform a task in the major field with confidence and to communicate the results effectively. Simply put, this degree requirement aims to provide a hands-on opportunity to allow students to link theory with practice. These qualifying projects are far from trivial, and each project is equivalent to three courses (9 credits) and can be completed full time in one term (one term = 7 weeks at WPI) or part-time in two to three terms. For the MBA degree at Foisie School, a Graduate Qualifying Project (GQP) is required to integrate management theory and practice, and incorporate a number of skills and tools acquired in the MBA curriculum. The project, often for an external sponsor, provides a capstone experience for MBA candidates and is completed individually or in teams. The project is embedded in a 3-credit, one-semester long (14 weeks) course. In addition to a written report, the project is formally presented to members of the Foisie community, outside sponsors and other interested parties.

This study focuses on the MQPs and GQPs completed by the business students at WPI and explores the values of these projects from two perspectives, namely education and research. The educational dimension is examined through an in-depth analysis of student project reports and a survey of alumni of the past fifteen years to understand the impacts of the projects on their personal and professional growth and career development. The research dimension asks if a linkage from project advising to scholarly work exists, and if yes, what characteristics of a student project are most likely to lead to scholarly work, such as a teaching case, conference presentation, conference proceedings, journal article, or grant proposal. The profile of a project that will potentially lead to a faculty intellectual contribution is explored through a faculty survey. This paper presents our initial findings, discusses the implications, and offers some directions for further improvement and implementation of industry sponsored projects to exploit their value in business education and research.
TEACHING BRIEF

Interpreting Videogames into Classroom:
a Game-Designed Operations and Supply Chain Management Course

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ABSTRACT

The traditional classroom lectures are increasingly less attractive to the younger generation that enter higher education. University students in business major crave for more real-world exposure and hands-on work. Based on the games in learning literature, we design an introductory Operations and Supply Chain Management course as a multiplayer RPG, following the stream of game-informed learning. We apply various principles found in videogames that make learning a more fun and immersive experience, and provide a proposed course syllabus design.

Subject Areas: Undergraduate Education, Classroom Dynamics, Experimental Learning, Pedagogical Approaches, Videogames, Gamified Course Design, Game-Informed Learning, Multiplayer Games, Alternate Reality Games.

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INTRODUCTION

“The content of video games, when they are played actively and critically, is something like this: They situate meaning in a multimodal space through embodied experiences to solve problems and reflect on the intricacies of the design of imagined worlds and the design of both real and imagined social relationships and identities in the modern world.” – James Paul Gee

Transfer of academic knowledge taking place in the university classroom, most commonly, takes form of lectures. The typical classroom formation that consists of rows of desks and the lecturer in the front of the room hasn’t changed much from 17th century European universities, and neither has the interaction by which knowledge is transferred. Professors and lecturers, over time, have come up with various ways of transferring knowledge that deviate from the typical classroom lecture – lecture slides, flipped classroom, etc. Recently, more attention is directed to the use of videogames (for the purposes of this paper we use the term ‘videogame’ in a comprehensive manner so as to include all platforms of modern digital games: video consoles (Playstation4, Xbox One, etc); PC; mobile devices, etc.. However, it is to be distinguished from ‘board game’).

The attitude towards videogames in the learning literature can show stark differences. Behaviorists, following Thorndike (1913) and Skinner (1968), consider the learning process a reinforcement through stimulus-response and repetition. Thus, videogames are often criticized upon behaviorist ground for ‘reinforcing’ violent behavior in children and young adults.

However, behaviorism has been accused of ignoring the private, mental processes inherent in individual human beings, leaving no room for human subjectivity (Bogost, 2007). The constructivist theory of learning, following Piaget (Brainerd, 1978) and Vygotsky (1978), assume that the learner “constructs” knowledge individually, that learning is inseparable from the learner’s interaction with the environment (Bogost, 2007). It also focuses on “learning by doing”, thus viewing videogames as a tool that teaches abstract principles that service general problem-solving skills and learning values (Bogost, 2007).

“... more generally it encourages the learner to experiment within knowledge domains freely, without fear of incompetence due to incomplete mastery.” (Bogost, 2007)

Lee Sheldon (2012) proposes a unique and innovative alternative of designing a “multiplayer classroom”, or coursework as a multiplayer game in which the students will be players of the game. While integrating
computer software to educational methods is not exactly a novel endeavor, designing a whole course as if it were a multiplayer game has not been tried widely.

We design a ‘game-informed’ syllabus for BUS 355: Operations and Supply Chain Management, which is an introductory course and also a required course for undergraduate business students at the University of Rhode Island. In the remainder of this article, we illustrate the reasons to design said course as a game identify the issues and challenges we face as instructors of said course and provide an outline of a multiplayer-game-design syllabus of BUS 355. We start by these two questions: Why are students not happy in the courses we teach, and how can we make them happy?

LECTURE VS. GAME

Games have formed an integral part of human life from ancient times. From sticks to dice, checkers to go and chess, elaborate set of playing cards, board games and modern videogames, it is one of the most popular pastimes in which we engage ourselves in. We play games because they are fun activities that give us unique sense of joy, engagement and achievement, and we sometimes immerse ourselves in them so much that some would say that we are addicted to them.

What makes games so fun and immersive? Jane McGonigal (2011) identifies the four defining traits of a game, in other words, what makes games so much more fun and immersive than reality itself: a goal, rules, a feedback system, and voluntary participation (McGonigal, 2011, p.21). The goal provides a sense of purpose; the rules unleash creativity and foster strategic thinking; the feedback system provides motivation; and voluntary participation establishes common ground and ensures a safe and pleasurable activity. These four traits, when generalized, can be measures of human interactions and experience.

A typical lecture course, where the lecturer speaks and the students take note, would have a goal: to transfer knowledge, to get a good grade, etc. It would also have rules: punctuality, academic honesty, classroom civility, etc. The feedback system for the course would be the graded homework assignments, answers to questions, and eventually, the final grade. It is important to note that while the feedback for games are constant and immediate, that of lectures are not. In a videogame every small decision, every keystroke or mouse click the player makes matters, and the results of those decisions are immediately realized visually. This, in a lecture, is not the case. Many scholars have identified ‘immediate feedback’ as one of the essential elements to be implemented in a game-based or game-informed course (Gee, 2005; Jackson, 2009; Mayo, 2009).
The typical classroom lecture also lacks is the voluntary participation. The university curricula often times cannot assure the voluntary enrollment, as many students, especially in their junior and senior years, have to take certain required courses in order to qualify to graduate. The classroom interaction of a typical lecture is limited in its participatory possibilities. In line with voluntary participation, academics have found in various research that incorporating a high level of learner control or autonomy to be one of the most important features of videogames that can enhance learning (Jackson, 2009; Mayo, 2009; Vogel et al., 2006)

McGonigal (2011) draws from positive psychology that certain categories of intrinsic rewards are key to human happiness: satisfying work; the experience, or at least the hope, of being successful; social connection; and meaning.

Clear goal and actionable next steps for achieving the goal are the elements of satisfying hands-on work. If the goal is clear and achievable, however challenging, failure in the process can be even more rewarding than achieving the goal itself. Repeatability, which comes standard in most videogames but not in the classroom, is key to eliminating fear of failure. According to Sir Ken Robinson’s popular 2006 TED talk,

“…by the time they get to be adults, most kids have lost that capacity. They have become frightened of being wrong. And we run our companies like this. We stigmatize mistakes. And we're now running national education systems where mistakes are the worst thing you can make. And the result is that we are educating people out of their creative capacities.”

THE GENERATION QUESTION

The generation that constitute current undergraduate student body is often referred to as the “millennial generation”. The term “millennial” commonly refers to those that are in college from the early 2000s to late 2010s (Bergman, 2011) They are more confident, assertive, entitled – and more miserable – than ever before (Twenge, 2006).

On average, they are overconfident, have high expectations, report higher narcissism, are lower in creativity, are less interested in civic issues, and are less inclined to read long passages of text. They are highly confident of their abilities and received higher grades in high school despite doing fewer hours of homework than previous generations.
They also believe in equality regardless of ethnicity, gender, or sexual orientation.
(Twenge, 2013)

Another characteristic of the younger generation is that they have been exposed to IT devices such as PC, cell phones, smartphones, and videogames from their early childhood. As a result, they accept information quite differently from the generation that teaches them. Prensky (2001) points out that “Today’s students are no longer the people our educational system was designed to teach” (cited in Jackson, 2009). Jackson goes on to conclude,

Considering the amount of time and passion some students devote to videogames (Prensky, 2006), to reach future generations of digital natives, perhaps countering school norms is what is called for. If we as educators do not do what is necessary to adjust to the cognitive structures of digital natives, computers may replace us. (Jackson, 2009)

RECENT TRENDS IN THEME

In order to create an immersive environment to which students can relate themselves, we explore the characteristics of video games that attract massive volumes of players. Recently, the videogame market has seen a rise of AAA games, meaning games that entail: long development periods; large, increasingly multinational teams; big budgets on development, marketing, and promotion; and are generally related to high quality and large player base. In short, they are the videogame equivalent of blockbuster movies. These blockbuster games also tend to form a franchise that continue to publish sequels with new contents in similar world view. Some of the most popular among the games in this category includes: Halo, Grand Theft Auto, Call of Duty, Battlefield, Medal of Honor, Assassin’s Creed, Fallout, Diablo, World of Warcraft, Metal Gear Solid, Final Fantasy, etc.

These games, although they may differ in genre and world view, have a common characteristic: epic scale. McGonigal (2011) defines “epic” as something that far surpasses the ordinary, especially in size, scale, and intensity (McGonigal, 2011). Epic scale empowers the player to achieve something much bigger than oneself – with epic contexts, epic environments, and epic projects.

In these epic-scale games, the player assumes the role of: an elite spy or special forces soldier (Call of Duty, Battlefield, Medal of Honor, Metal Gear Solid), a lone hero on a treacherous quest (Final Fantasy, Diablo, World of Warcraft, Fallout), and a member of a secret order (Assassin’s Creed). The players are
granted extraordinary powers and resources, and are expected to accomplish seemingly impossible missions.

Another trend in recent videogames is the rise of open-world games. Open-world games provide players with nearly infinite possibilities in the way the game is played, the missions are cleared, and the contents that are derived from the game. This open-world construction also strengthens the multiplayer experience, empowering players to either team up with other players to achieve an epic mission, or engage in a player-versus-player (PvP) gameplay. The openness of gameplay essentially grants the players a co-authorship of the narrative which, as aforementioned, is identified by many scholars as an improving element for learning.

*Learner control over navigation through tasks and activities is a surprisingly important feature of effective learning games. The metastudy by J.J. Vogel et al. (2006) found learner control/autonomy to be one of the few easily identified predictors of enhanced learning outcomes.* (Mayo, 2009)

We examine the baseline scenarios and basic designs of some of the recently-released games that possess both of the characteristics listed above: *Rise of Tomb Raider* (January 2016); *Assassin’s Creed: Syndicate* (November 2015); *Hitman* (March 2016); and *Tom Clancy’s The Division* (March 2016).

*Tomb Raider* (Square Enix, 2016), marking 20 years of franchise since 1996, features an iconic virtual archaeologist, Lara Croft, who is on a quest she inherited from her late father. The most recent publication, *Rise of Tomb Raider*, depicts the early days of Lara Croft on her career. She tracks down the “Divine Source” that grants immortality, fighting against an ancient order of enemies. Although there is a set path of story missions to follow, the player can always go back to previous mission areas to explore more.

*Assassin’s Creed: Syndicate* (Ubisoft, 2015), following the tradition of depicting actual historical places, events, and people, is set in the Victorian era London. The player can switch back and forth between to characters – the Frye twins, Evie and Jacob. Against the order of the Templars that dominate the city, they must win the hearts and minds of the people of London, not to mention eliminate the Templars that plague the city. The player can conquer parts of the city by any preferred order, and the city is available for a thorough exploration.
Hitman (IO Interactive, 2016), also a franchise started in 2000, takes the player to when the protagonist, Agent 47, was first recruited by the International Contracts Agency. The player must accomplish the early missions of 47 in order to progress with his memory. The most recent version of the game releases a new target with certain interval, and the destination of mission grants infinite freedom of play.

Tom Clancy’s The Division (Ubisoft, 2016) is set in New York, present day. The description on the official homepage reads:

“New York is in trouble. A devastating epidemic sweeps through the city and in the wake of the disease basic services fail one by one. Without food and water, the streets are in chaos and new factions rise to profit from the mayhem. Amid the chaos, a classified unit of self-supported sleeper agents known as The Division is activated and tasked with one mission: take back New York.

Fighting to piece the city back together one block at a time, the agents of The Division will combat the chaos driving New York to the brink and be face not only the effects of the deadly virus, but the rising threat of those who unleashed it. New York is in trouble. And it’s up to you to save the city.”

Tom Clancy’s The Division is unique in the industry because it incorporates a third-person shooter (TPS) element with massively multiplayer online role playing game (MMORPG). The physical space is set not in a mythical medieval kingdom, but present day downtown Manhattan. Also, it is inspired by an exercise actually conducted in 2001 by National Security Council (NSC) members responding to a hypothetical smallpox bioterrorist attack, augmenting to the plausibility of the scenario.

Ubisoft, publisher of Tom Clancy’s The Division, provides an interactive game online called Collapse: The End of Society Simulator. The simulator allows the player input his/her own address, and then goes on to show how the choices one makes spreads the disease and eventually leads to massive casualties and societal collapse. An essential part of the promotion efforts for the game, the simulator reinforces the immersion to the scenario of the game, making it personal to every player.

We thus use the world view of The Division to be applied in our course design.

THE NEED FOR A WORLD
The academic approach on using videogames in the classroom has been twofold: game-based learning, which embeds curricular content in an actual digital videogame, e.g. educational/serious games (Mayo, 2009); and game-informed learning, which implements the processes of learning that are identified in successful gameplay, informing the learning processes themselves with the good learning principles of gaming (Gee, 2005; Jackson, 2009), e.g. ‘gamifying’ the course.

Game-based learning, with the direct use of technology, graphic contents, and other technical aspects that augment to the immersion, tend to work more efficiently than game-informed learning. However, Begg et al. (2005) argue that the game-based learning approach can be problematic, because it may be based on the premise that learning is not fun, but it can be made fun simply by introducing a game element. It must be noted that when gamers are encountered with a series of dull or frustrating experience with a game that exceeds their tolerance limit, they are very likely to never go back to playing it.

Jackson (2009) relates the reason of students being “engaged all the time” in the Reacting to the past” courses at Barnard University, described by Denby (2000), to Gee’s “identity principle” where learners learn by taking on different roles (Jackson, 2009). Begg et al. (2005) conclude that “Rather than perceiving games solely as a platform in which learning content can be delivered, educators might offer more effective learning opportunities by integrating the learning principles within games into teaching practice” (cited in Jackson, 2009).

Sheldon (2012) depicts his experience of designing and conducting a multiplayer course in the university classroom and proposes that the method be tried in every level of education, including graduate, and in every discipline and subject. The course designed by Sheldon was on game and character design, but he also provides feedback from teachers and professors in various subjects, and conclude that multiplayer classroom is indeed applicable in other subject areas.

Business students in the undergraduate level are generally goal-oriented, and appreciate real-world case studies and hands-on work, and even crave for them. They are apt in relating an academic topic to a real world example, whether it be based on personal experience or major corporate cases or events. They are also compliant to the university and college standards of conduct and requirements. A multiplayer game design will greatly benefit in heightening the engagement of the students to the subject topics and activities.

In order to do so, we apply the world view of The Division into the classroom. We use students’ real names instead of avatar names, because the scenario is based on the reality. We also incorporate the
PSAid annual national contest for smart compassion. For details of the humanitarian logistics project, see Özpolat et al., (2014)

ALTERNATE REALITY

According to Sheldon (2012), alternate reality game (ARG) uses the real world as a platform, often involving multiple media and game elements, to tell a story that may be affected by participants’ ideas or actions. It is a type of pervasive game, where the line between the game and reality is blurred and is difficult to distinguish one from the other (Sheldon, 2012).

Historically, in fact, most ARGs, like most computer and video games, have been designed simply to be fun and emotionally satisfying. But my research shows that because ARGs are played in real-world contexts, instead of in virtual spaces, they almost always have at least the side effect of improving our real lives. – McGonigal (2011)

Blurring the line is often used as a franchise effort in videogame industry, taking form of collectibles, or “artifacts”. Often complementary to limited editions or “season pass”, which includes all updates and downloadable contents (DLCs), firms offer action figures, static figures, miniature models, diorama items, 1:1 replica of key items in the game, or spin-off books that depict the world view of the game.

Tom Clancy’s The Division offers a replica of an agent’s watch, a stand-out feature in the game, in its limited edition. A book titled New York Collapse: A Survival Guide to Urban Catastrophe is also published, bearing the name of a fictitious author. The book is filled with clues and removable artifacts such as map, metro card, and poster, as well as hand-written notes of the fictitious owner of the book, who also appears in the game as a non-player character (NPC). The book gives the reader/player a unique sense of immersion at the verge of the game and reality.

The feature of ARG, incorporated into the multiplayer classroom, could be packets of instructions, hints for quiz and exam separated into multiple pieces that students have to come together to figure out, and password-protected document files of which password hints are hidden within the college building, etc. By engaging in actual physical activity, the students will be more engaged in the activities, and eventually, the topics of the course.
COURSE OVERVIEW

On the first day of the semester, students are introduced to the game design of the course, along with the semester schedule. The students will be given a questionnaire with questions on when and where they were born, their major, their goals, their non-academic passions, etc. This background will form the context for each of the agents in the game. This will give them a sense of urgency, because the scenario will force their normal lives to a halt and they will have to resolve the situation in order to win their lives back.

The course is based on the students reading the chapters of the textbook, taking quizzes, and presenting on the reading. The instructor has several options regarding lecturing: Although spending the whole class time with traditional lecturing is to be avoided and replaced by student presentations and discussions, as well as real-world case presentations, the instructor may choose to complement the student presentations with explanations and examples, or secure half of the class time for lectures on basic concepts or application. The quiz element enforces the students to keep up with the weekly reading.

The Level and experience point (XP) system builds toward the final grade. Starting from 0 XP at Level 1, students must surpass the threshold of Level 10, or 630 XP, to pass the course. The XP of all available activities listed sums up to 1030, which is slightly higher than 1,000 for Level twenty. This is to allow to mitigate the loss of XP due to inevitable absence or slightly poor performance in certain areas. In the lower levels, the XP required to level-up increases with each level, resembling the structure of MMORPGs. The XP structure for levels higher than 10 resembles percentages associated with letter grades. The status of every student is to be immediately accessible via classroom portal (Sakai) or other media.

Student groups are called Waves, resembling the categorization in The Division into First Wave, Second Wave, etc. This would be the equivalent for guilds in medieval-world RPGs. The wave membership is fixed within the first two sessions of class. Wave activities include the Humanitarian Logistics Project (HLP), chapter reading presentation, peer review, etc. Additional projects, such as Ocean State Circuits, Inc. Forecasting Project (Kroes, Chen, & Mangiameli, 2013), as well as video resources from TED, RSA, etc., are to be added to the available activities for students to be able to have ample opportunity to level up.

Another activity required in the early Activation stage is to conduct a research on the professors in SCM area in the college, and then visit those professors as a wave, present their agent credentials, and obtain proof of contact establishment. The form of proof is to be left to the students’ discretion and creativity.
Students will be able to choose which chapter they will read and present. Although the structure of the textbook is to be generally respected, other than the first two chapters coming first, students will be able to determine the order of chapter progress. The larger categorization of chapters, or “Parts”, will be represented as different geographical areas with different goals to achieve in the game scenario.

Reading and quiz is labeled as Resource Gathering. Based on these resources, they will conduct Crafting activities, which include writing individual summaries, team report for HLP, and individual case analyses. Raids represent presentations and exams. These activities include possible extra credit for superb performance, labeled “raid strategies”.

The Dark Zone, in Tom Clancy’s The Division, is a dangerous zone where the pathogen is still active and violent factions are in power. Agents explore the Dark Zone for valuable loots, such as weapons and equipment. In the classroom, the Dark Zone will represent real-world case analysis presentations and current news article presentations relevant to the topics of the course.

Attendance and participation is crucial and will be taken into the XP system for evaluation, as well as a peer evaluation within Waves. The 5-point Likert scale for group performance is labeled as Wave Leader, Raid Leader, Equipment Crafter, Support and Civilian, in a descending XP attribution.

As the semester progresses, ARG elements are to be introduced with packets and hint-hunting. Along with the introduction of ARG packets, the progress tracking mechanism requires further development and resource allocation. Although the course is designed in a way that does not involve actual videogames, the progress of the game needs to be available to students to allow close-to-instant feedback. Also, a visual representation of the progress the whole class makes in securing the city needs to be accumulated and represented to give students a sense of collective achievement. In the city progress representation, the accumulative progress of the class will be translated into the world of The Division.
APPENDIX: PROPOSED COURSE SYLLABUS DESIGN

University of Rhode Island
College of Business Administration

BUS 355-0006: Operations and Supply Chain Management

Fall 2016
Instructor: Hee Yoon Kwon
Email: hykwon@uri.edu
Office: 216 Ballentine Hall
Office hours: Mon: 2:50 PM – 3:50 PM
            Wed: 1:50 PM – 2:50 PM
Lecture hours: Mon, Wed: 11:30 AM – 12:45 PM (Ballentine 251)

Objectives

- Provide you with the core knowledge in:
  - the foundations of operations function in manufacturing and services;
  - interaction of business units across functions; and
  - interaction of firms across the supply chain.

- Familiarize you with the new supply chain management concepts to see the bigger picture where competition is not between firms but between whole supply chains.

- Develop information literacy by conducting web-based research analyzing data using Excel, and developing public service announcements.

- Improve your teamwork and oral communication (presentation) skills.

Format

This course is designed as a multiplayer game. You are the players. You will each create an avatar that will represent you in the game.

A deadly virus has swept the world, and the society as we know it has collapsed. Far too many have died of disease, and more are suffering from the lack of basic resources: shelter, food, water, electricity, communications, and transportation. To make matters worse, violent factions have risen in the wake of disorder to exploit what remains and terrorize the survivors.
You are a member of a government sleeper agency, created for a doomsday scenario like this. You were living a normal life when the outbreak happened, and shortly after, you were activated. Once activated, you are to respond and act on your own discretion to save what remains of our society and restore order. Together, you must gather resources and reestablish the infrastructure around the city. These are extremely hazardous tasks, but if humanity is to survive tomorrow, we must fight today.

You will work alone and as a team. You will scavenge to gather vital resources (chapter reading and quizzes), craft materials and equipment (chapter summaries and group reports), and engage in battles against dangerous and powerful enemies (presentations, midterm and final exams). As you progress through the journey as an agent, your agent will gain new skills and level up.

At the beginning of the semester everyone in the class will fill out a name and background story of their agent, and set a personally distinguishable item. The next task is to decide a nickname and the base of operations for your wave. A wave is a group of agents. Wave size and membership will be determined by the final class size. You will begin your mission in your base of operations. However, progress with your missions will take you outside of your base, the neighborhood, the classroom, and into the treacherous Dark Zone.

**Grading Procedure**

You will begin on the first day of class as a Level One agent. Level twenty is the highest level you can achieve. Your class letter grade will be determined by your final level. You must be at least Level Ten to pass this course.

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<thead>
<tr>
<th>Level</th>
<th>XP</th>
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<tbody>
<tr>
<td>Level Twenty</td>
<td>1,000</td>
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<td>Level Nineteen</td>
<td>930</td>
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<td>Level Eighteen</td>
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<td>Level Seventeen</td>
<td>870</td>
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<td>Level Sixteen</td>
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<td>Level Fifteen</td>
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<td>Level Fourteen</td>
<td>770</td>
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<td>Level Thirteen</td>
<td>730</td>
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<tr>
<td>Level Twelve</td>
<td>700</td>
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Your level will be determined by experience points (XP) on a 1,000 XP scale. You gain XP by defeating mobs, solving puzzles and crafting.

**Activation**

- Solo: Create your Level One agent. (Written, 1 page, 15 XP)
- Solo: Introduce your agent to the class. (5 XP)
- Solo: Get placement in a Wave. (5 XP)
- Wave: Create a name and insignia for your Wave. (5 XP)
- Wave: Contact Establishment: Gather intel on the SCM professors in the CBA and their specializations, then present your agent credentials in return for a proof of meeting. (5 XP)

**Resource gathering**

- Solo: Read chapter of textbook and answer quiz at the beginning of class. (10 XP each quiz)
- Wave: Upload your PSA for the annual PSAid national contest. (15 XP each agent)

**Crafting**

- Solo: Read chapter of textbook and write a summary. (Written, 10 XP)
- Wave: Gather intel on Humanitarian Logistics and write a report on Cash Donation. (Written, 5 pages, 50 XP each agent)
- Wave: Based on your intel on Cash Donation, create a public service announcement, either in print or video format. (75 XP each agent)
- Solo: Analysis of a case of your choice (Written, 3 pages, 75 XP)
**Raids**

- Wave reading presentation (50 base XP each agent, 1 presentation per wave)
- Quick Match Team: 2-player reading presentation (75 base XP each agent, cannot team with fellow wave agent) **OR**
- Solo: 1-player reading presentation (75 base XP, but easier than above)
- Wave: Present your experience creating the public service announcement. (75 base XP each agent)
- Developing clever strategies to defeat presentation mobs can increase XP gained by up to 50 additional XP. (See Raid Strategies below)
- Solo: Defeat Level Boss (Midterm Exam, 125 XP)
- Solo: Defeat Season Boss (Final Exam, 150 XP)

**Dark Zone Survival Skills**

- Quick Match Team: 2-player presentation on a real-world case analysis relevant to chapter topics and concepts (10 XP each agent)
- Solo: presentation on a current news-article relevant to chapter topics and concepts (10 XP)

**Agent Evaluation**

- Solo: class attendance (140 XP total, 5 XP per day of attendance)
- Wave: Peer Review Secret Ballot – **Extra credit.** 0-50 possible XP as follows:
  - Wave Leader 50 XP
  - Raid Leader 40 XP
  - Equipment Crafter 30 XP
  - Support 20 XP
  - Civilian 0 XP

Grading is rigorous. Spelling, grammar, and punctuation must be proofed. Total XP will suffer otherwise.

**Hints**

Information that may help you succeed in your mission:

- Careful readers will notice that from Level 10 up the XP system mirrors percentages associated with letter grades.
- We will supplement the XP chart with a Leaderboard that indicates the number of students at each level to help track personal progress, particularly in the lower levels.
**Raid Strategies**
As noted above, clever raid strategies can increase the amount of XP awarded for defeating presentation mobs. As in any MMO, successful raids are built upon the attempts of others. Your basic slideshow presentation where you read off the bullet points like some tired clerk will only qualify for the base number of XP. Other methods such as videos, contests, performances, and any other method to engage the audience are encouraged, even expected.

**Attendance and conduct**
Attendance will be taken, and will count toward the final grade (see above). You are expected to attend every class. Assignments are due at the beginning of every class. Late assignments will fail to achieve the highest amount of XP for that assignment.

Plagiarism, submitting assignments written by others, and other forms of academic misconduct are governed by university policy. In a word: DON’T.

Classroom conduct: Participate with civility and an abiding appreciation for the power of words. Respect others, even those who hold opposing views.

**Required Text**

**Special Needs**
Any student with special needs (such as disability or health issues) should bring this to attention as soon as possible, no later than the second week of class so that we may arrange reasonable accommodations. As part of this process, please be in touch with Disability Services for Students Office at 330 Memorial Union, 401-874-2098.

**All materials in the syllabus is subject to updates and patches.**
REFERENCES


Shapiro, Jordan (2016). MindShift guide to digital games and learning


Navigating Multicultural Classrooms: An Exploration of Personal and Group Development in the ESOL Classroom

Quinn Orcutt, Bay Path University

ABSTRACT

As our world becomes more and more diverse, multicultural classroom environments is becoming the norm. The Teach for America Project (2011) has found it imperative that our educators develop ethnic and cultural literacy across students, prepare students’ attitudes and values for living in a diverse community, and teach multicultural social competency for students to have a healthy interactions with people from different backgrounds. Such education requires social change through teaching and learning. Our educators should be able to create a cultural learning style for their classrooms that breaks through the bonds of cross-cultural conflicts and stereotyping.

Adicichie (2009) explains in her TED presentation that there can be a very specific danger when working with people from different cultures: the single story perspective (TEDGlobal). It can be easy to fall into the danger of a single story, in which we have a specific, whether realistic or not, image in our minds of what a culture is like and how those from that culture think and behave. This study focuses on ESOL classes, the adult education program which seeks to provide “educational services to adult learners.” This important program offers English for Speakers of Other Languages (ESOL) services, basic skills (reading, writing and math) tutoring, beginner English conversation classes and literacy development for resettled refugees (Gray House, 2016). This study examines the difficulties in creating an environment devoid of stereotyping, cultural biases, and inaccurate perceptions.

References


Negotiation: Gender Impact
Quinn Orcutt, Bay Path University

ABSTRACT

For the past fifty five years, since the beginning of the first wave of the feminist movement, women have been entering the workforce in high numbers. No longer are women in the U.S. primarily stay at home moms, but rather they are present at board meeting and other high managerial positions. However, despite this cultural shift, women’s salaries are still less than their male counterparts in similar fields and positions.

According to the Bureau of Labor Statistics for the U.S. Department of Labor (2015), in the third quarter of 2015, women who worked full time had a median earnings of $721 as opposed to men who were earning a median of $889. Without going into other demographics, such as race or ethnicity, which show an even higher wage disparity, the U.S. Department of Labor reported that white women made 80.5% compared to their male counterparts. Among the major occupational groups, persons employed in full time management, professional, and other related occupations, men were earning $1,381 as compared to women’s $1,000.

A major contributing factor for these wage inequalities could be more than just blatant sexism, but instead could be reflective of the differences between how men and women negotiate salaries. This research explores the concept that if negotiation under the same circumstances can have a different result based on the gender of negotiator.

Providing Students with Practical Experience in an Internet Analytics Course

Bhupinder S. Sran, Ph.D, DeVry University
Lajos Balogh, MBA, DeVry University

The use of Internet analytics tools has become widespread over the last decade. It is no longer good enough for an organization to simply create a website and hope it is successful. Rather, it is important that the organization be able to capture and analyze user activity on the website. Web analytics tools allow an organization just to do that.

As the use of these tools becomes a business necessity, there is a need for workers and managers who are knowledgeable in the application of these Internet analytics tools. Therefore, academic institutions are offering courses and programs focused on this area and in business analytics in general. Providing the students with practical, hands-on experience with web analytics tools in a structured way can be quite a challenge in these courses. There are a few problems that must be overcome. First, web analytics tools are constantly changing. This requires that we continually update the courses, which makes it difficult for an academic institution to design course materials that could be used over one or two years, without making major changes. Second, depending on the size of the university, there may be several sections of the course which are taught by many different faculty members. As the courses change, it is necessary to provide continuous training for these faculty.

This study presents covers several aspects related to teaching Internet analytics. These include the demand for business analytics skills, a survey of programs offered by academic institutions, challenges faced in developing Internet analytics courses and various models for providing students with hands-on experience with web analytics tools. The study also presents a simulation tool developed to provide students with practical experience with web analytics tools. Other course elements of an actual web analytics course are also discussed.
RIPPED FROM THE HEADLINES:
SHARING BEST PRACTICES TO ENHANCE MANAGEMENT
LEARNING THROUGH CURRENT EVENTS

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Abstract Submitted to the 2017 NEDSI Annual Conference, Springfield MA
SUBMITTED ABSTRACT:

Ripped from the headlines:

Sharing best practices to enhance management learning through current events

Professors teaching disciplines such as management, human resources and organizational behavior often face student apathy toward course content, as students can view the content of such courses as overly theoretical and impractical to their current lives. This is especially true among undergraduate students. Relevance and personal interest are important contributors to knowledge accumulation for today’s millennial students who express a strong desire for practical application in learning.

This gap between educators’ need to teach foundational theories and students’ desire for practical insights and connections to their current interests presents a pedagogical challenge. Thus, the application of theories and skills to current events, especially in disciplines such as management, human resources and organizational behavior, presents a prime opportunity for professors to illustrate how classroom theory connects to the real world. Incorporating current events into the classroom environment also serves as a great tool for both professors and students to keep abreast of the dynamic world around them.

This presentation focuses on incorporating current events into classroom curriculum to enhance student learning and engagement with the subject matter. Both the need for and benefits of this approach will be highlighted. Various pedagogical methods for incorporating current events will be presented, and a forum created for sharing innovative practices teaching with current events.

Keywords: current events, practical concept application, student engagement
EXPANDED ABSTRACT

In the past few years the interest in online learning has peaked as most institutions of higher education now offer fully online courses and blended courses. This has led to a large number of research articles (e.g., Boling, Hough, Krinsky, Saleem, and Stevens, 2012; Camarero, Rodriguez, and San Jose, 2012; Grinnell, Sauers, Appunn, & Mack, 2012; Kraut, Resnick, Kiesler, Burke, Chen, Kittur, and Riedl, 2012) being written about online learning, including the use of teams in the virtual classroom.

Although teams have been a pedagogical tool used in face-to-face classrooms for a long time, they have always held challenges for both students and instructors. The use of teams in virtual classrooms does not seem to eliminate these challenges and in fact brings up some new challenges. Creating effective team assignments for online classes often takes trial and error and can therefore be a trying experience. Students are also often frustrated with online learning teams. In a qualitative study of online learning teams, it was found that students felt that problems with teams stemmed from lack of student conscientiousness, asynchronous communication, limited student availability, and lack of leadership (Grinnell et al., 2012).
Students often take online courses for the flexibility it provides them and being required to work in a team cuts into that flexibility.

Based on our own anecdotal evidence, we have found that many instructors are not using teams in their virtual classrooms because they find them wrought with problems and too difficult to manage. Despite these challenges forgoing the use of teams in online classrooms, may be leading to missing out on rich learning experiences. Online interactions have been found to be one of the most positive things about the online classroom (El Mansour & Mupinga, 2007), so the more of these types of experiences that can be included in an online classroom the better. In fact, findings have shown that a main reason students drop out of online classes is feelings of isolation and disconnectedness (Willging & Johnson, 2009). The use of teams can provide a way for students to interact and connect with each other during the learning process.

This paper and the presentation will discuss ways to effectively incorporate teamwork into online classrooms. The technological tools for using online teams have gotten so much better than when distance learning first began and today’s students have gotten better at using these tools since they have grown up with technology. In addition there are numerous pedagogical techniques, such as using team leaders (Grinnell et al., 2012) and peer teams to lead online discussions (Rourke & Anderson, 2002) that can be incorporated to make the process more effective. We will discuss the research behind some of these tools and techniques and also give examples of how we use them in our own online classrooms.
SOURCES


THE EFFECTIVE SUPPORT FOR JAPANESE SOJOURNER ELLS IN AMERICAN SCHOOLS

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ABSTRACT

Temporary and voluntary international people have been classified as sojourners. They plan to return home and their acculturation in a new country is therefore relatively stress-free and unproblematic for both the host communities and sojourners. However, there are many Japanese sojourners English Language Learners (ELLs) who are struggling to adjust to U.S. schools and culture. The most critical issue is language. The English education in Japan is behind because of the education system in Japan and the linguistic distance between English and Japanese. In addition, the cultural difference is another barrier for ELL. Almost all Japanese people have no chance to know about American school system. This research focuses on Japanese sojourner ELLs and presents how to effectively support young students. The results of our survey showed that the anxiety of Japanese parents about their children’s social adjustment and academic achievement, including English proficiency. Their anxiety is not always recognized in American school. On the other hand, we found suggestion for improving their situation by both of mainstream classroom teachers and ELL teachers in an American school through individual interviews and surveys. Reflecting these results, we proposed some solutions both for parents and teachers with developing a guidebook. It will contribute to more efficient support both for families and teachers.

Keywords: Sojourner, English Language Learners (ELL), Japanese, American School, Adjustment, Cultural Gap, English Proficiency.

INTRODUCTION

Almost all Japanese people have been surrounding by homogeneous circumstance because of the geographic and ethnic condition. Most children and parents have no international friends because there are few foreigners living in Japan. We have very little opportunity to learn about life abroad. Unfortunately, the information from mass media is biased. Only the stereotype is imprinted to Japanese people. The Japanese are very isolated from the rest of the world. The situation cause issue for Japanese ELLs in American school, in terms of their adjustment [1].

In addition, the English education in Japan is behind [2][3]. Although Japanese Ministry of Education standards decided to begin mandatory weekly English lessons in public schools for fifth and sixth grade students, it just started in 2015. Moreover, the worst problem of English education in Japan is just focus on entrance examinations to high school or college. After the examinations, the English knowledge is no longer needed because it focuses on only grammar and reading. It is not helpful for a direct communication at all, such as having questions for teachers, discuss about a topic with peers and
making friends. As a result of these factors, the tragedy occurs when Japanese people have to go abroad for business or academic purpose. They have a difficulty to adjust to new abroad country because of the lack of knowledge of American culture and English. It brings cultural shock to Japanese people.

The purpose of this study is to investigate the current situation experienced by Japanese ELLs in Massachusetts throughout questionnaire surveys for Japanese parents and teachers, and to propose strategies from findings from parents. First, an in-depth understanding of issues surrounding these children is presented throughout the surveys. Next, it describes how the children, parents, ELL teachers and classroom teachers currently deal with these issues. Finally, what they can do to better help these children adjust to American schools is discussed with the strategies.

**METHOD**

We believe that knowing the difference is critical for Japanese parents at American schools because Japanese sojourner ELLs and parents are from a homogeneous society, and they have no idea how to adjust to a diverse society. From past studies [4][5][6], many differences were found between American and Japanese schools.

The participants in the study survey are Japanese ELL parents and ELL and regular classroom teachers. In order to understand the current situation that experienced by Japanese ELLs, questionnaire surveys were firstly conducted for 22 Japanese parents in Massachusetts. To find a best practices to help with Japanese ELLs smooth adjustment, this study created an open-ended question survey to collect data on what information would be the most useful in facilitating Japanese ELLs adjustment and success in American schools. The survey data collection was done in person.

Next, by focusing on the analyses of surveys and interviews with the Japanese parents and teachers, the following themes are identified an discussed- (1) the differences in the school culture of Japan and the U.S. and how this impact’s students’ adjustment and ability to learn, (2) how social and academic support is provided by parents, (3) effective strategies to support Japanese ELL students in American schools. Throughout these surveys and interviews, this study figures out the specific problems of Japanese sojourners in learning and adapting to the U.S. classroom and provides strategies on how to solve these problems.

**RESULTS OF QUESTIONNAIRE SURVEY: FINDINGS ABOUT PARENTS**

The profile of these Japanese parents and students in the survey

![Figure 1 Result of Question 1: How many years have you and your child(ren) been in the U.S.?](image1)

![Figure 2 Result of Question 2: What is the grade is your child(ren) in?](image2)
The profile of these Japanese parents and students is as follows. 48% of the sojourners families stayed for under two years at Question 1 as shown in Figure 1, and 57% of the children are in grades K-2 at Question 2 as shown in Figure 2. Most Japanese sojourners stay in the United States for a short time, and their children are young when they come to the United States.

The Circumstance that Surrounding Japanese ELLs and Their Parents

Figure 3 Results of Questions 3-6: Circumstance that surrounding Japanese ELLs and their parents

Figure 3 shows the results of Questions 3-6 for the circumstance that surrounding Japanese ELLs and their parents. At Question 3 “What has changed in your children’s school life since you came to the United States?”, more than 80% of parents answered that changes happened in their children’s school life, both good and bad. The rest of the parents answered that their children did not reach school age before they came to the United States, so they cannot compare American schools to Japanese schools. In fact, 61% of parents mentioned their children faced some trouble and difficulties in adjusting at Question 4.

Some of the difficulties included the following. One child got bullied, and another fell out with their classmates. Some classmates put the blame on a Japanese child whenever things went wrong, some children got seriously homesick and did not want to go to school, and so on. Overall, the most challenging issues involved interpersonal relations. To address this problem, the students need to learn to communicate with teachers or parents and ask for their help. In Japan, it is not common for students to bring these problems by themselves to the teacher though, they have to learn to speak out their problem in the U.S.

The same thing can be said about Japanese parents. They do not communicate with teachers frequently except for the special occasion in Japan. However, 96% of parents, replied “Yes” to the question “Have you ever contacted teachers when you have any questions?” at Question 5. It means that it is necessary to communicate with teachers in American schools. When they find their children’s problems, they usually go first to the ELL teacher at the school who is a Japanese native speaker. Also, the second choice was the mainstream classroom teacher or other Japanese parents.
Besides these significant interpersonal problems, the daily routine is also entirely different. A mother mentioned, “everything is different from Japanese school... lunch, snack, the morning circle, timetable and so on.” Then, another mother added “my child and I had had to spend time with anxiety in the American school, each issue is not significant and serious, but always we had to live with constant fear.” It is a stressful situation. Also, there are many rules in American schools and there is a school handbook in each school. But most parents do not know there is a handbook, thus, it is hard to access it. Also, in Japan, Japanese parents get used to getting explanations about school rules or daily routines from someone at the school and they know about the Japanese school system. But in the U.S., parents have to go and ask teachers or other parents.

**The participation by Japanese Parents in the American Schools**

As far as parents’ participation in the school is concerned, the participation rate of Japanese parents in American schools is remarkable. 83% of Japanese parents have an experience working as a volunteer at the school from Question 6 as shown in Figure 3. They have helped with the school festival, been a chaperone on field trips and organized the returning of books at the library. These parents replied that the volunteer work was very significant because they were able to get to know about the American school system and it enabled them to communicate with teachers and other parents. In fact, the school in Massachusetts has a transparent system that encouraged Japanese parents to participate in volunteer work at the school. They have a Japan food booth at the school festival, and the outstanding volunteers who work at the school library are Japanese mothers. We asked the parents about their concerns at the time immediately after their children entered the American school. All parents answered the same thing. How can their children be comfortable in the American school? Also, they think the final success for Japanese children is acquiring English proficiency to communicate with peers and learning about multicultural differences. They focus on the social development rather than the academic achievement. The first reason is that their children are in lower grades, and the other reason is it is not clear how academic achievement is measured for them. A mother mentioned “I don’t know what my child studies at the school because they do not bring their textbooks and notebooks home like in Japan. And I don’t know the curriculum and schedule.” Under these circumstances, it is hard to understand the academic goals for their children.

It is found that Japanese students and parents faced challenging issues in American schools in relating to other people and in understanding the American school system. For students and parents, it is necessary to communicate with teachers or other parents when they have questions or problems. The parents become involved in volunteer work at the school, and they find it to be a positive experience because this helps them to get the feel of how an American school functions.

**COST-BENEFIT ANALYSIS AND STRATEGY ON EFFECTIVE SUPPORT FOR JAPANESE SOJOURNER ELLS IN AMERICAN SCHOOLS**

Table 1 proposes strategies to assist ELLs in adjusting to American schools from findings about parents. For each strategy, there is an actor(s) and a receiver(s) of the action. The actors include children and parents at home, and mainstream teachers, ELL teachers and other Japanese parents at schools. Receivers of the actions can be the same members of the actors and other parents. Both actors and receivers of the action will use Japanese, English or both languages. Moreover, the required time and cost are estimated as one of inputs resources. Therefore, the effectiveness of each strategy are simulated as output.
<table>
<thead>
<tr>
<th>No.</th>
<th>Strategies</th>
<th>Actor</th>
<th>Receiver of Action</th>
<th>Language</th>
<th>Time</th>
<th>Cost</th>
<th>Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Parents and children learn how to communicate with teachers.</td>
<td>Home School</td>
<td>Parents</td>
<td>Home</td>
<td>Yes</td>
<td>No</td>
<td>larger</td>
</tr>
<tr>
<td>2</td>
<td>Parents consult with ELL teachers first when they find their children are having trouble in the classroom.</td>
<td>Home School</td>
<td>Parents</td>
<td>Home</td>
<td>Yes</td>
<td>No</td>
<td>shorter</td>
</tr>
<tr>
<td>3</td>
<td>Parents consult with mainstream teachers first when they find their children are having trouble in the classroom.</td>
<td>Home School</td>
<td>Parents</td>
<td>Home</td>
<td>Yes</td>
<td>No</td>
<td>middle</td>
</tr>
<tr>
<td>4</td>
<td>Parents and children learn about the American school system and rules of American schools.</td>
<td>Home School</td>
<td>Parents</td>
<td>Home</td>
<td>Yes</td>
<td>No</td>
<td>shorter</td>
</tr>
<tr>
<td>5</td>
<td>Parents ask teachers or other parents voluntarily when they have an issue.</td>
<td>Home School</td>
<td>Parents</td>
<td>Home</td>
<td>Yes</td>
<td>No</td>
<td>shorter</td>
</tr>
<tr>
<td>6</td>
<td>Parents work as volunteers at their children's school.</td>
<td>Home School</td>
<td>Parents</td>
<td>Home</td>
<td>Yes</td>
<td>No</td>
<td>longer</td>
</tr>
</tbody>
</table>
It is found that effective results can be achieved at the strategies No.4 and 5 with little cost in a short period of time. With regard to the strategy No.4 “Parents and children learn about the American school system and rules of American schools”, Japanese parents and children are aware that there are differences between Japanese and American schools. However, they do not know what these differences are. Thus, learning about American schools is the first action that Japanese parents and children should do.

At the strategy No.5 “Parents ask teachers or other parents voluntarily when they have an issue,” Japanese parents and children get to know immediately that they should take action voluntarily in American schools. Many items are prepared in Japanese schools; school guidebook, timetable of the schools or list of learning materials, and the parents can obtain it before entering schools in Japan. In addition, Japanese parents are not used to have questions to teachers and other parents about school system. On the other hand, parents cannot get anything without voluntary action in American schools.

Also, it is found that “parents and children learn how to communicate with teachers.” at the strategy No.1 is essential. It means that listening and communicating to other people well will be effective to build a good relationship for both parents and children. Especially, communication way in American school is different from Japan. The important thing is that parents should not leave children alone. They have to manage the beginning tough period in American school together.

**SUMMARY**

This study investigated the current situation experienced by Japanese ELLs in Massachusetts throughout the questionnaire survey for Japanese parents and teachers, and proposed the strategies from findings from parents. Even though there is a gap between American and Japan schools in terms of linguistic or cultural difference [4][5], we proposed some strategies for helping ELLs in their transition. Future study should present the findings about teachers from the survey results and make a feedback to the participants from the strategies proposed in this paper.

**ACKNOWLEDGMENTS**

The authors would like to thank to the teachers and Japanese parents for participating this survey. This research was partially supported by the Japan Society for the Promotion of Science (JSPS), KAKENHI, Grant-in-Aid for challenging Exploratory Research, JP16K12829, from 2016 to 2017.

**REFERENCES**

The Other (Secondary) Beneficiaries of the VITA Program

ABSTRACT

The Volunteer Income Tax Assistance (VITA) program is an Internal Revenue Service (IRS)-sponsored program that the federal government established more than 40 years ago. The core objective of the VITA program is to provide underserved communities and low-to-moderate income individuals who cannot afford professional tax preparation services with free tax filing assistance.

In an attempt to minimize costs while maximizing the benefits – and broadening the coverage - of the program, the IRS entered into strategic partnerships and alliances with colleges and universities nationwide. These alliances with colleges and universities have created many unique opportunities for accounting faculty and their universities that have not been fully exploited.

Although the VITA program has been around for more than 45 years, very little has been written about the program and the opportunities and benefits that it provides. The few articles written about the program focused on the establishment of the VITA program; the skills acquired by student volunteers; using the program as a teaching tool; and certain best practices. However, very little has been written about benefits to faculty and their sponsoring universities involved with the VITA program. Could the reason be that many accounting faculty members are not taking full advantage of the opportunities afforded them by the VITA program? In this article, the authors contend that a VITA program can provide a vehicle for doing more than providing free, high-quality tax preparation services to low- and moderate-income individuals. In our view, a properly designed and managed VITA program can help students, faculty, and administrators alike, without detracting from its major tax-preparation focus.
VITA for All – The Many Possibilities for Students in A School of Business

ABSTRACT

The Volunteer Income Tax Assistance (VITA) program is an Internal Revenue Service (IRS) initiative that provides free tax preparation assistance to underserved communities and to low-to-moderate income individuals who could not afford the services of professional tax preparers. Over the years, the IRS has looked for strategic partnerships that could reach a greater number of beneficiaries. One key area identified by the IRS was colleges and universities. Many colleges have embraced the VITA program as an opportunity to provide hands-on tax preparation experience almost exclusively for their accounting students, but not for other students in the Schools of Business (SOBs).

This paper reports on a model for VITA piloted at York College (City University of New York) that provides a chance for all students of the SOBs to operationalize skills learned in their classes and to contribute to an umbrella philanthropic program. The undergraduates of York prepared taxes for clients (accounting); launched a marketing campaign for VITA (marketing); provided financial literacy for clients and assessed the financial impact of the program (finance); and recruited and scheduled the VITA volunteers (human resources). This CUNY case study demonstrates the possibilities for programmatic integration afforded by the VITA initiative for SOBs.
How Multinational Firms Conduct Resource Leverage: A Dynamic Capabilities Approach

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Abstract: The goal of this paper is to conceptualize a framework to depict how international firms leverage their strategic resources. We introduce the perspective of dynamic capabilities into the integration and responsiveness (IR) framework. In this framework, resource replication, redevelopment and recombination are developed as the foundational dynamic capabilities, by which we illustrate multinational firms’ conduct in transforming their resource base in response to the strategies implemented. This paper suggests that resource leverage, by resource replication, redevelopment and recombination, should serve as a potential set of yardsticks to measure how well a firm employs its dynamic capabilities, especially in regard to its global business.

Keywords: dynamic capabilities view, International business, IR framework, resource leverage

1. Introduction

International diversification is considered a key means to enable a firm to capitalize on business opportunities in the global market, as well as a way to diversify risks. With the increasing globalization of business, the question of how to manage a successful international enterprise is of growing importance. The popular framework used in research on international business strategy is the integration-responsiveness (IR) framework (Bartlett and Ghoshal, 1987). The strength of this framework lies in its ability to providing guidance to firms in their selection of appropriate strategies in the early stage of international expansion (Daniels et al. 2011).

In order to conduct these strategies fruitfully, it is necessary to successfully leverage strategic resources in the international market. This requires expending efforts on transferring necessary resources, such as from parent companies to local subsidiaries, as well as between subsidiaries. Managers might assume that resources can be easily transferred between the business units of an international firm, but this might not always be the case (Szulanski and Jensen, 2006). In fact, a firm that fails to effectively distribute or transfer its resources will experience performance erosion, as expected (Fang et al., 2007).

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With this view in mind, it is pertinent to look into the issue of linking strategies implemented by multinational firms and how these firms manipulate their resource endowments in favour of strategic formulation and implementation (Eisenhardt and Martin, 2000; Helfat et al., 2007; Teece et al., 1997; Teece, 2007). This study, therefore, introduces the perspective of dynamic capabilities into the IR framework.

Dynamic capabilities relate to a firm’s ability to “extend, create or modify its resource base” (Helfat et al., 2007, p.1); these have been viewed as critical in regard to firms maintaining a sustainable competitive advantage (Teece et al., 1997). Possession of the dynamic capabilities view (DCV) is of essential relevance to research on international business management, since even if multinational firms are able to recognize early on what strategies would be appropriate, determining how they leverage their existing resources, and introduce or develop new resources in a proper fashion would be still challenging (Fang et al., 2007). This is because the global business environment is much more dynamic and unpredictable than that of local business (Daniels et al. 2011).

The aim of this research is to contribute greater understanding regarding the potential patterns of resource leverage in relation to how multinational firms manipulate their resources in order to develop their strategies. Our research focus is thus to explore the resource leverage patterns through a distinct taxonomy of strategies of multinational firms as defined by the IR framework, such as global strategy, international strategy, multidomestic strategy and transnational strategy.

In the following section, we review the theoretical foundations of the paper in the IR framework, the perspective of dynamic capabilities, and resource leverage. Then we conceptualize a potential theory for how multinational firms conduct resource leverage based on the IR framework. Followed by the discussion in which we illustrate the role of dynamic capabilities in leveraging resource base between parent companies and subsidiaries, and across subsidiaries. Finally, we address the conclusion of this study.

2. Theoretical Background and Underpinnings

Global Integration and Local Responsiveness (IR) Framework

The integration-responsiveness (IR) framework emphasizes the two imperative pressures exerted by the external environment that a firm encounters during its operation in international marketplaces, namely: global integration and local responsiveness. Global integration relates to industry forces that necessitate worldwide business resource deployment to maximize production efficiency. In contrast, local responsiveness refers to firms’ pressure to adapt to local requirements, especially local customer preferences. On the basis of the perception of the degrees of pressure related to these two factors, a firm will adopt a respective strategy to pursue its desired performance, which includes four generic strategies: international, multinational, multidomestic and global (Daniels et al. 2011).

International strategy

International strategy is adopted when a firm aims to leverage its strategic resources by expanding into foreign markets. With this strategy, parent companies have the ultimate control over value activities of foreign subsidiaries. Although some slight modifications of the value chain can be made by subsidiaries abroad, new products and processes originate from managers
at headquarters. This strategy works well when firms’ foreign competitors lack the core competence that these firms possess, and the industry conditions do not require a high level of standardization and local responsiveness. However, it is possible that with the one-way view from parent companies, firms may misread new opportunities in foreign markets as parent firms may not understand local markets (Daniels et al. 2011).

**Multinational strategy**

Multinational strategy is founded on the philosophy that every country has localized, either physical or nonphysical, features that comprise its uniqueness and difference. Therefore, firms employing this strategy achieve performance by strongly adapting its value activities to local customers’ preferences. This leads to the highest level of decentralization of authority from parent companies to local managers due to their better understanding of the local markets. This strategy makes sense when firms face the high pressure of local adaptation and low need for cost efficiency resulting from global integration (Daniels et al. 2011).

**Global strategy**

Global strategy refers to firms’ selling common products on a global scale with minimum variation. This strategy is applicable when firms face a compelling need for worldwide consistency but weak pressure for local adaptation. As a result, firms are more concerned about the cost efficient advantage by dispersing their value activities in optimal locations and selling standardized products or service across countries. A great level of standardization also requires strong control from parent companies, so firms risk failing to address disruptive changes that may occur in local markets (Daniels et al. 2011).

![Figure 1. The Integration-Responsiveness Framework Strategy](image)

**Transnational strategy**

Transnational strategy posits that the interconnected customers, markets and industries in the global business environment require firms’ value activities that enable firms to simultaneously exploit the competitive efficiency of global integration and local adaptation. Transnational
strategy is considered a compromise between global strategy and multidomestic strategy. The unique aspect of this strategy is its emphasis on knowledge-sharing across value activities; this means that managers are required to obtain insights into the best practices achieved by firms’ operation, and then to diffuse them throughout the global value chain. This action, in turn, allows firms to standardize some value activities, while also adapting other activities to local requirements. As such, the primary source of competitive advantage for firms using this strategy is to advance the exchange of knowledge and resources across firm units, while this concurrently requires operational efficiency in standardization, local adaptation and global knowledge-sharing (Daniels et al. 2011).

In sum, the IR framework has been viewed as a successful and useful model to evaluate the strategy formulation of multinational firms. This framework, with its strength of a distinct taxonomy of international strategy, is applied popularly in research into the field of international business management, such as MNC strategies, subsidiary management, and the divestment of foreign subsidiaries (Devinney et al., 2000).

**Dynamic Capabilities View**

Whether a firm can develop and sustain its competitive advantage has been of a critical issue in the strategic management field. In the current disruptive business environment, firms not only struggle to build competitive advantage but also find it hard to maintain this advantage, for reasons such as: rapid technological development, globalization, and severe reaction from competitors (Wang and Ahmed, 2007). As such, there is increasing attention paid by research of strategic management to the emerging dynamic capabilities view as this is generally considered as an appropriate theoretical perspective to address this concern.

Before the appearance of the DCV, the five forces model and the resource based view (RBV) were considered as the two dominant theories for dealing with the problem of firms seeking sustainable performance. According to the five forces model, industry structure (barriers of entry, power of customers, power of suppliers, substitute products and rivalry among competitors) is the main factor affecting a firm’s decision in regard to positioning itself in the industry. In contrast, the RBV focuses on firms’ resource base in building competitive advantages. Based on the two fundamental assumptions, resources are allocated heterogeneously across firms and move imperfectly across firms, the RBV posits that firms’ possession of a resource that is valuable, rare, inimitable and non-substitutable (VRIN) will lead to a sustainable competitive advantage (Barney, 1991). However, in the changing environment, industry boundaries become blurred, market players (i.e. buyers, suppliers and competitors) are ambiguous and shifting; resources are easily imitated and substitutable (Eisenhardt and Martin, 2000). A static analytical approach, as these two models are, might fail in expressing how firms sustain their performance in a rapid changing environment. Therefore, the five forces model and the RBV have often been criticized as static and failing to explain why some firms can sustain success in turbulent environments while others cannot.

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1 In Barney’s (1998) later discussion, the VRIN framework was redeveloped to become the VRIO framework, by including “organizational support”, emphasizing that only do firms processes (organization) support to deliver “value”, “rareness” and “imperfect imitability” of resources. That is, how firms exploit resources to reinforce its performance is critical to sustain its competitive advantage. This paper uses “VRIO” instead of “VRIN” in the later discussion.
The DCV is generally considered to extend the RBV by explaining how VRIN resources are created, and how firm resources are continuously transformed to address changes in the business environment. Originating from Teece et al. (1997), this concept has been refined and improved by many other authors (e.g. Eisenhardt and Martin, 2000; Zollo and Winter, 2002; Winter, 2003; Zahra et al., 2006; Wang and Ahmed, 2007; Helfat et al., 2007). This paper uses the definition available from Helfat et al. (2007, p.1), defining dynamic capabilities as a firm’s capacity to “purposefully create, extend, or modify its resource base”. In addition, to address the confusion of the relationship between dynamic capabilities and firm performance, the current study affirms that dynamic capabilities are not necessarily directly linked to firm performance or competitive advantage; instead, dynamic capabilities facilitate the change in firms’ resource base in response to the changing context in which firms operate (Helfat et al., 2007).

One of the major discussions on the DCV concerns how dynamic capabilities lead to a firm’s competitive advantages, and even sustainable competitive advantage. Still, such a discussion lacks consensus not only in theoretical discussions, but also in empirical research on how dynamic capabilities actually contribute to performance. Despite this, there is agreement that the value of dynamic capabilities in regard to firm performance lies in the resource configuration that managers build using dynamic capabilities (Eisenhardt and Martin, 2000; Helfat et al., 2007; Doving and Gooderham 2008). In particular, Teece (2007) notes three dynamic capabilities underlying firms’ resource configuration: sense, seize and transformation. Sense capability is firms’ ability to identify and shape opportunities; seize capability relates to firms’ ability to capitalize on the opportunities sensed, and transformation capability refers to maintaining firm performance by enhancing, combining, protecting and, when necessary, reconfiguring firms’ resource base. The inference is that the outcome of the ‘sense – seize – transformation’ process is that VRIO resources are created continuously, which can explain firms’ sustainable competitive advantage. Due to its great contribution to research on dynamic capabilities, this paper uses the ‘sense – seize – transformation framework’ of Teece (2007) to explicate the dynamic resource leverage of firms in the context of the IR framework.

The DCV is a nascent perspective; its foundation level issues are the process of building and development, and that it is impossible to avoid conflicting ideas regarding this construct. Typical examples include Teece et al. (1997) and Eisenhardt and Martin (2000). These two papers have had a dual influence on research on dynamic capabilities (Peteraf et al., 2013). In more detail, Teece (1997) affirms that dynamic capabilities can explain how firms achieve and sustain competitive advantage in times of rapid change. However, Eisenhardt and Martin (2000) challenge this perspective, and posit that it is impossible for dynamic capabilities to be a source of sustainable competitive advantage, regardless of market dynamism.

This conflict stems from their different assumptions regarding dynamic capabilities (Peteraf et al., 2013). While Teece et al. (1997) depict dynamic capabilities as large, complex organization routines, Eisenhardt and Martin (2000, p.1113) suggest that such suggestion is true in moderate markets, but in extreme markets, dynamic capabilities are “simple routines”, “continuously unstable” and “subject to potential collapse”. Even in moderate markets, while Teece et al. (1997) posit that these capabilities are heterogeneously distributed across firms, Eisenhardt and Martin (2000, p.1105) describe them as the best practices which are “significant commonalities across firms”, becoming more substitutable, and thus unable to contribute to sustainable performance.
The inconsistency in theoretical constructs of dynamic capability leads to a criticism regarding its varying theoretical foundation, lack of clarity, and a suggestion of a replacement by a work on strategic change tied to fuller theories of strategic organization (Arend and Bromiley, 2009). Although the DCV is not the only way to deal with firms’ strategic change in a rapidly changing environment, the difference in dynamic capabilities is that they deal with the strategies required to sustain a capability-based advantage in the context of environmental change; this is largely missing from research on change management (Helfat and Peteraf, 2011). Due to this significant role, there have been many efforts to reconcile opposing views to reach a unifying theoretical foundation in research on dynamic capabilities (e.g. Helfat and Peteraf, 2009; Peteraf, 2013; Easterby-Smith et al., 2009).

In addition to our awareness of the role of dynamic capabilities in how firms manipulate the resource base, we recognize that Teece’s (2007) contribution in the ‘sense – seize – transformation’ framework for firms to respond to, and interact with, the environmental dynamics. Therefore, this study introduces the DCV into the IR framework in order to expand the DCV to a view in explicating the dynamic resource leverage of multinational firms’ behaviour in the global competition context.

**Resource Leverage**

Resource leverage has been generally suggested as the extraction of additional value from under-utilized resources. Danneels (2007), exploring technological competence leveraging, suggests that if a firm lacks competence to leverage its current technologies toward a new market (as market competence), it will be forced to operate in the current market trap. Such contribution could be considered as a macro view on resource leverage since the RBV views marketing competence and technologies as the elements of the resource base of a firm (Barney, 1998).

As Danneels (2007) suggests, technological competence refers to a firm’s ability to design and manufacture a product, including design and engineering know-how, product and process design equipment, manufacturing facilities and know-how, and procedures for quality control; market competence is made up of market-related resources, such as knowledge of customer needs, preferences, purchase procedures, and distribution and sales access to customers. These two are definitely firm resources (no matter they are resources, capabilities, competencies or knowledge) according to the RBV (Barney, 1998). By Danneels’ (2007) example, to avoid a market trap, firms are required to apply its technologies into a new market. That is, firms would be able to conduct market diversification by leveraging marketing resources (or competencies) on technological resources (or competencies).

In addition, for a much systematic and comprehensive discussion on resource leverage, Helfat and Peteraf (2003) suggest the processes, such as resource replication, redeployment or recombination, should be critical to illustrate how firms exploit or approach new opportunities. Replication refers to transferring a capability to another market. For example, abovementioned Danneels’ (2007) contribution in technological competence leveraging would be a paradigm of capability replication. Recombination of capabilities is applicable when an original capability needs to be altered by either redeveloping it or combining it with another capability. For example, in the manufacturing sector, firms’ existing manufacturing capability can be combined with a capability of using information technology to improve their manufacturing efficiency. Redeployment may take the form of sharing of a capability between the two similar businesses (Helfat and Peteraf, 2003). Canon exemplifies a case of capability redeployment.
Capabilities of improving dealer effectiveness, production-line and expediting product development in the camera business were transferred to improve those aspects in the photocopier business and vice versa (Markides and Williamson, 1994).

In sum, resource leverage is able to be viewed as a specific approach in which firms manipulate their under-utilized resources in order to develop or renew the resource base. It is a faster and less risky choice for firms to innovate and capitalize on new opportunities. Research into this field has identified three generic capabilities in which firms leverage their resource, such as replication, recombination, and redeployment. This paper strongly views resource leverage, referred as to these three capabilities, as a type of dynamic capabilities, and by which we develop a framework to illustrate how multinational firms perform dynamic resource leverage.

3. Resource Leverage under the IR Framework

International Strategy: Resource Replication

Firms with an international strategy have weak pressure for local adaptation. Therefore, to expedite their penetration into foreign markets, resource replication, which entails reproducing the same capabilities in another geographic market (Winter and Szulanski, 2001), is an appropriate choice. The result of replication strategy is the creation of organizations that are capable of producing and offering their products or services locally. As such, a successful replication cannot be achieved without an effort to adapt to the local environment. Generally, there are little significant alteration of these product offerings to be necessarily made to respond to local customer preferences, and strategic asset features from parent companies still need to be maintained (Winter and Szulanski, 2001). Wal-Mart, for instance, has reaped consistently high profits by systematically expanding into new geographic markets based on a strategy of capability and resource replication (Helfat and Peteraf, 2003). This replication includes a logistics capability that involves standardized procedures for warehousing, handling and inventory management, in combination with standardized resource configurations that cluster stores around company distribution centres (Helfat and Peteraf, 2003).

Multidomestic Strategy: Resource Recombination and Replication

Multidomestic strategy is characterized by firms’ high pressure for local adaptation. In this strategy, each foreign subsidiary has the ultimate control of its business so that they can obtain the highest extent of local responsiveness. As such, modification of the initial resources obtained from parent companies is inevitable. Depending on the extent of the difference between the home country and target market, the modification of firms’ resources may be insignificant or significant. In particular, if the home country and local market are similar, firms can replicate the original resources in the local market. This situation is the same as in the use of international strategy. However, if the idiosyncratic features of the local market prevent firms from employing their original resources, they need a resource recombination capability to modify the current resources and develop new competence (Galunic and Rodan, 1998; Helfat and Peteraf, 2003). For example, mass media channels are commonly favoured by customers in the U.S. to access product information, whereas personal selling is preferred by customers in Brazil (Daniels et al., 2011). Therefore, firms expanding to Brazil have to build a sales force to tap Brazil consumers. This means that firms’ original market competence is modified and combined with the capability to offer personal selling to form a new market competence for the Brazil market.
As mentioned above, great effort to modify the original resources for local adaptation is needed when a great difference between markets exists. In such situations, however, it is better for firms to first accurately replicate the original resources to local subsidiaries and seek to modify the resources for local adaptation thereafter (Szulanski et al., 2002). In regard to this idea, Martin and Brush (2003) show that accurate replication of a portion of a manufacturing process to another plant within a firm provides the basis for subsequent adaptation and renewal of the capability within the recipient plant.

To sum up, to leverage a resource in using a multidomestic strategy, firms may replicate its original resources when the difference between the home country and local subsidiaries is insignificant; otherwise, firms may recombine their initial competence and develop new ones for local responsiveness. In this situation, firms’ effort to precisely replicate a resource should be done before efforts are made to respond to local markets, hence yielding a better result.

**Global Strategy: Resource Replication**

The logic behind global strategy is that firms use standardized products to neutralize the challenge of global integration. As such, standardization of value activities across local subsidiaries leading to firms’ advantageous cost structure is generally a foremost concern (Daniels et al., 2011). To accomplish this goal, a high level of replication of initial strategic competences across firms’ foreign affiliates is highly recommended. The case of Zara provides an illustration. Zara is a famous brand in the fashion industry, with a network of 1,292 stores globally spread across 72 countries (Daniels et al., 2011). The extent of standardization of value activities across Zara’s local subsidiaries is extremely high. This can be seen through the accurate replication of the original store style in the home country in all the other stores outside it; around 80 to 85% of products sold by Zara are relatively similar across countries. In addition, Zara’s core processes (order fulfilment, product design and manufacturing and production) that are vital to its success are applied consistently across its stores and manufacturers (Lewis et al., 2008). In short, replication of strategic competences when Zara expands in the global market enables the parent company to control its standardized value chain, and is the source for Zara’s advantages in short production time and frequent store replenishment with new items.

**Transnational Strategy: Resource Redeployment, Recombination and Replication**

Diffusion of knowledge across a multinational firm’s value activities is the primary source of competitive advantage for firms that adopt a transnational strategy (Daniels et al., 2011). Knowledge diffusion may take the form of resource redeployment, replication, or recombination. As transnational firms operate in a broad scope of businesses, knowledge in one business unit may be redeployed to another business unit operating on the basis of similar technological principles. For example, Honda’s experience in managing its existing dealer network for small cars was deployed to improve the management of its largely separate network for motorbikes (Markides and Williamson, 1994). Besides, resource replication is also suggested to quickly transfer experience in a certain field to the same fields across firms’ geographical markets.

Similar to multidomestic strategy, knowledge transfer in transnational strategy will be accomplished through resource recombination when firms seek to customize according to local customer preferences. The outcome of this process is the creation of a new competence that can possibly be replicated on a global scale. For example, in its operation in Japan, Procter & Gamble (P&G) realized that the low storage space in most typical Japanese homes makes
Japanese customers prefer products that do not significantly occupy space, while simultaneously offering the same quality. This requirement encouraged the R&D unit in Japan to develop a technology that reduced the thickness of an infant’s diaper without reducing absorbency. This technology competence created value for P&G in Japan, and was subsequently replicated across P&G manufacturing units (Daniels et al., 2011).

In short, resource leveraging in transnational strategy results from knowledge recombination, redeployment and replication. Thereby, a best practice created to serve one region will be replicated in other geographic regions, redeployed to other related businesses, or recombined to adapt to local requirements. Under a knowledge sharing oriented system in transnational firms, ideas flow from one unit in one part of the value chain to the other parts. As a result, innovation will emerge more often, and in turn, lead to firms’ resource redeployment, recombination and replication on an ongoing basis.

![Figure 2. Resource leverage under the IR framework](image)

4. Insights into the Dynamic Capabilities View

Resource leverage of firms operating in international industries is a complex process, including transferring resources from parent companies to foreign subsidiaries and within these subsidiaries. Resource transfer requires firms’ capabilities in terms of resource allocation and transformation, which are facilitated by sensing, seizing and transformation capabilities supported by a series of sub-processes.

Expansion of firms’ business to a specific market abroad first requires firms’ knowledge and awareness of the local host country. This includes various conditions of the host country, such as the social, political, demographic and economic factors, as well as how to access the local labour force, distribution channels, raw materials, competitive offerings and other factors required for conducting business in the host country (Fang et al., 2007). Compared those multinational firms taken a global or international strategy, transnational and multidomestic companies need to spend more time and effort on sensing information in terms of those factors affecting local customer taste and purchase decisions because of the high pressure of local responsiveness. Information on local markets can be sensed from a few different channels, such as hiring local staff (Beamish and Inkpen, 1998), increasing ownership in case firms aligned with local firms to expand operations (Makino and Delios, 1996), or using the services of a local consulting agent. Concurrently with obtaining knowledge of the local host country, firms’
evaluation of the original processes for improvement purpose prior to transferring operations abroad on a wide scale is also imperative.

After business opportunities are sensed, to capitalize on these opportunities, preparation for the process transfer is carried out and an actual transfer is performed. This includes the allocation of related resources to improve the initial process, and then transferring them to foreign subsidiaries. Investment in resource redeployment or recombination is further needed to multidomestic and transnational firms in response to local adaptation. However, replicating and transferring a competence within a firm, as well as between firms, is rather difficult and unlike simply transferring information for reasons such as: the tacit nature of knowledge, coherence of routines underlying a competence and context dependence (Teece et al., 1997). The more complicated a competence, the more difficult it will be to transfer effectively (Fang et al., 2007). As such, a firm needs to equip itself with learning capabilities, especially knowledge codification capabilities to acquire in-depth knowledge (Teece et al., 1997; Zollo and Winter, 2002). Besides, firms may encounter some obstacles during the course of transferring knowledge, especially in the context of transnational firms, which is characterized by continuous sharing and changing to adopt the best practices across markets. These impediments may be loss aversion, established assets, and complacency that make recipient firms less willing to change, or to suffer from bias and error in changing. Therefore, in such a situation, firms need to be unbiased in their assessment of opportunities, changes in the market, and competitor reactions, by a structural change involving cross-function ideas in decision-making.

Simultaneously with investment in technology transfer, customer-related competences need to be developed to serve new markets, such as building new distribution channels, designing advertising strategy, pricing and promotion strategy, and leveraging brand reputation. Due to low pressure for local adaption, international firms can develop these market-related competences by replicating them from the home market country. After staffing foreign subsidiaries, firms can convey necessary skills to the personnel in local locations so that they can commercialize the product or service. In multinational and transnational firms, competences to serve new markets vary according to the countries, from similar to quite different from initial market competences. Therefore, in some countries, new market-related resources need to be developed. Similar to technology transfer, market competence transfer and development require firms to have strong learning capability. Firms with a learning capability in acquiring new customer competences will facilitate firms’ ability to identify which resources are needed to serve those customers, as well as how to utilize and allocate resources to develop them.

For a multinational firm to fully capitalize on international diversification, it must transfer its strategic knowledge between the parent companies and subsidiaries without making that knowledge concurrently available to competitors (Kogut and Zander, 1993). Thus, the ability to monitor and protect firms’ knowhow and intellectual property is needed, especially when a joint venture is adopted for the purpose of expansion. When subsidiaries are able to serve local markets on their own on the basis of the skills and competences of the parent companies, periodic and even continuous resource orchestration is necessary to maintain the evolutionary fitness and performance. For example, resource management skill is needed to avoid malfeasance and the mishandling of increasing assets when firms grow. It is also imperative to prevent barriers to communication due to unnecessary procedures arising along with firms’ growth over time. A structural change in management, especially decentralization is encouraged in response of rapid changes in the market, as well as local adaptation, specifically
for transnational and multidomestic firms. Learning capabilities also need to be improved over time to enhance the ability of firms to develop technology and market-related resources, which effectively facilitates knowledge sharing, innovation and local responsiveness on an ongoing basis.

In sum, leveraging resources in international diversification in the rapidly changing business environment entails a continuous process of orchestration of the resource base of firms. Such process should be supported by the performance of sense, seize and transformation capabilities. Business success and stable performance are determined by the successful development of these dynamic capabilities. However, investment intensity in these dynamic capabilities varies according to the types of internationalization strategy that multinational firms adopt, determined by the extent of reconfiguration, realignment and transformation of the resource base. Of the four strategies mentioned above, the investment intensity in sensing, seizing and transformation capabilities increase respectively from international and global strategy to multidomestic strategy and to transnational strategy.

5. Conclusion

International diversification is a way in which multinational companies leverage its strategic assets beyond the home country. According to the IR framework, operating in a global environment, a firm can adopt one of four generic strategies: international strategy, multidomestic strategy, global strategy, or transnational strategy. Leveraging resources in multinational firms can be done through resource replication, redeployment or recombination. In our discussion, we have illustrated that resource replication is suggested for a multinational firm implement an international or global strategy; resource replication and recombination to multidomestic strategy; resource replication, recombination and redeployment in transnational strategy. To successfully transfer a resource from one market to another requires a firm to possess and implement dynamic capabilities in sense, seize and transformation aspects. The possession of these dynamic capabilities will facilitate a firm to transfer its resources among its global affiliates and ensure that its operation continuously matches the requirements of the environment in which it operates. We, therefore, suggest that resource replication, resource redevelopment and resource recombination should serve as a potential set of yardsticks to measure how well a firm employs its dynamic capabilities, especially in regard to how it conduct resource leverage in implementing strategies in the global competition context.
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Multinational Corporations: The Case of Brazil

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Abstract

Brazil is one of the fastest growing global economy. This research concentrate on Brazil’s operating environment, the presence of multinational corporations (MNCs) in Brazil, and their competitive strategies. Considering the high numbers of MNCs operating in Brazil, the sustainably practices of these corporation, their strengths and weaknesses are investigated. In addition, this study explores the future economic potentials of Brazil. The last part of the research, examines the areas that protection of environment and sustainable practices are imperative to protect the rain forest, land use, human resources, and animal and plant species.
Abstract

For the last decade or so, tea consumption around the world has been undergoing a profound change. In the context of climate change, environmental degradation, resource problems and declining bio-diversity, it has been recognized that both domain of production and consumption need to change in tandem to achieve large gains in environmental sustainability. [1] The consumer demand towards sustainable tea is increasing as western individual consumers and nonprofit organizations are demanding more accountability in production from the corporations. Such demands, coupled with corporate social responsibility, make it imperative for corporations to sharpen their focus on sustainability issues in the industry. However, an all-out effort towards sustainable production and procurement is difficult to assume due to the socio-economic situations of the tea producing countries, where most of the tea is consumed. The aim of this research is to contribute to the understanding of the challenges in Sustainable Consumption and Production (SCP) in Indian tea industry and the drivers of corporate decisions in this context.

Key Words: Indian tea industry, Sustainability, SCP, Consumer Engagement, Base of the Pyramid, Smallholders, CSR

Introduction

The trend of sustainability in production and consumption pervades all areas of business decision making. Although early policy ideas can be traced back to reports by the United Nations, OECD and the World Business Council for Sustainable Development in the mid-1990s; policy attention accelerated after the 2002 World Summit on Sustainable Development in Johannesburg. There, the delegates called upon the United Nations Environment Programme and the United Nations Department for Economic and Social Affairs to develop a 10-year framework programme on Sustainable Consumption and Production. The most well-known and comprehensive definition of sustainability is found in the Brundtland Report: "Sustainable development is development that meets the needs of the present without compromising the ability of future generations to meet their own needs." [2] There is a growing consensus around the world that there is no alternative to sustainability. [3] Sustainability makes room for greater brand relations and reveals
a corporation’s trustworthiness and honesty. In the light of environmental degradation, demographical shifts and resource scarcity, it has become imperative that sustainability production issues are addressed in tandem with responsible consumption. [1]

Sustainability is considered as an economic state where the demands placed upon the environment by people and commerce can be met without reducing the capacity of the environment to provide for future generations. In the early 1970's the economic and social effects of environmental degradation, caused by the unsustainable use of natural resources and as a consequence of industrial activity, began to exert a pressure on industry to improve its performance. The combined influence of public and community opinion, environmental pressure groups, 'green' political parties, and the media, (at local, national and global level) targeted policy makers and brought forth a regulatory regime which demanded high levels of compliance of the large industrial organizations.[4]

Sustainable Consumption and Production (SCP) is a newly growing topic in research and policy discussions. As Geels et.al writes: the appeal and importance of the SCP agenda stems from the fact that it moves beyond the dominant focus on pollution control and green products, widening attention to the patterns of consumption that underpin the resource-intensity of everyday lives. In classic SCP research, there are two major identifiable positions: the Reformist position and the Revolutionary position. The academic and political orthodox position of the Reformist agenda focuses on firms pursuing green eco-innovations and consumers buying eco-efficient products. Second, the Revolutionary Position, which is a radical critique of the mainstream, advocates the abolishment of capitalism, materialism, and consumerism, and promotes values such as frugality, sufficiency, and localism. [1] For the purpose of research and analysis, I propose to follow the Reformist position of SCP, where production and consumption of green eco-efficient products are considered as the basic tenets.

The two dominant components of SCP agenda are consumption and production. The 1994 Oslo Conference defined sustainable consumption as the consumption of products and services that have minimal impact on the environment. In case of the tea industry, sustainable consumption is considered to be a key influential factor which has far reaching consequence for the stakeholders at the far end of the value chain. But, in the light of the fact that majority of the tea gardens are located in emerging economies; sustainable tea consumption in the domestic market becomes an alien issue. Consequently, the efforts at defining sustainability in the tea industry are created outside the country by a different group of consumers. Since SCP has been instrumental in shaping policy research, reports generated by non for profit organizations are found to be very useful. The first detailed effort on “Sustainable Issues in the Tea Sector” was published in 2008 by the Centre for Research on Multinational Corporations, a non-profit organization based in Denmark. Since 1973, they have been investigating multinational corporations and the impacts of their activities on people and the environment. Forum for the Future is another independent non-profit that works globally with business, government and others to solve complex sustainability challenges. In a conference organized by the Forum for the Future, a sustained effort was made for cross-sector collaboration to improve livelihoods, respond to climate change, and engage consumers in the roadmap to develop a sustainable tea industry for 2030. [6]
The degree to which sustainability enhances preference depends on the type of benefit consumers most value in the product category in question. [7] This concept is discussed in detail later in the paper. Customer engagement is one of the biggest challenges in the domestic tea market in India. The Forum report refers to consumer engagement as an effort where “they both demand more sustainable tea and reduce impacts associated with tea consumption.” [6] Though these reports are found to be statistically accurate where most data sourcing has been done through governmental agencies; they do not adequately address the social and economic variances in the consumption pattern of the worldwide tea consumers. Responsible consumer usually looks for tea that is grown with respect to the laborers and the environment. The high demand for sustainable tea mostly comes from EU countries and UK. [5] According to Forum for the Future statistics, two in every three of the Britons drink more tea than any other country in the world except Ireland. As tea industry reels from the demands of the global consumers to produce more sustainable tea, the majority of the tea drinkers in India care very little about whether the environment is affected adversely in tea growing efforts or about the working conditions of the tea garden laborers.

Although there is a fair amount of research available on the tea industry as such, sustainability concerns have not been addressed extensively in this important industry. The aim of this research is to contribute to the Sustainable Consumption and Production (SCP) discourse in Indian Tea Industry and shed light on the role or lack thereof of Smallholder tea producers and the Base of the Pyramid (BoP) buyers in the sustainability platform and the response of the multinational corporations.

Indian Tea Industry: A Glimpse

India’s tea industry is more than 170 years old. Since the British discovered “phanaap” in the northeastern foothills of the Himalayas, tea industry has grown to be one of the most organized industry sectors in India. The tea industry in India is world’s second largest tea producer and exporter, just behind China. [8] The country produces quality specialty varietals that are as highly regarded as wines from France and whisky from Scotland. [9] India produced 1207310 metric tons of tea in the year 2014.

![Tea Export Data for India](image)

**Fig.1 Tea export data, India: majority of produced tea is consumed locally**

The Indian tea industry has seen a new trend with the emergence of small growers and Bought Leaf Factories (BLF) which have created a paradigm shift in the industry with their comparative
advantage of low cost in labor and technology. Tea in India is grown by both smallholders (less than 10.1 hectares of cultivated land) and large estates (technically more than 10.1 hectares in size). [5] The latest available statistics on Indian tea as found in the Tea File of the Tea Board of India, the production of the Bough Leaf factory (BLF) section increased by 5.81%, which indicates small tea growers’ share in production. At this point, 33.85% of all production is being contributed by small growers.

As illustrated by figure 1, almost 80% of the Indian tea is consumed locally within India. The domestic market in India accounts for the largest consumption of black tea. [5] There has been a steady growth of worldwide consumption of tea since 2000. Yet, per capita consumption of tea in India is still one of the lowest in the world. This low figure in consumption can be explained in terms the staggering billion odd total populations. It also points to the fact of the economic condition of the majority of the buyers who are poor and cannot afford to buy in big quantities. The domestic tea market is predominantly a loose tea market, constituting around 60% of the total tea consumption, while the rest is served by packaged tea. [5]

In the case of tea industry in India, the plantation model of the industry works with its own structure and development mechanisms and it relies on Plantation Labor Act for its operations and regulations. Various Acts and Rules regulate and control the structure and function of plantation sector in India. The plantation sector works in a strong network of capital assets and has its own methods of addressing issues such as the quality of green leaves, production of ‘made tea’, and social, economic and social responsibilities at the field and market levels. [10] The auction buyers are mostly big tea companies having their own network of blending, packaging and marketing. Many industry insiders believe that the large buyers have co-operated with the brokers on the auction floor to keep tea price low. [11] Hence actual growers can do very little regarding the price of their tea. They cannot hold on to their stocks for a long time and so have to be satisfied with the price fixed by the big buyers. Thus producers end up selling tea to the big buyers.

The three major corporations that source tea from India are: Tata Global Beverage (India), Unilever (British Dutch) and Twinings (USA). All these three corporations are engaged in sustainability efforts in the recent years. The Indian government has ample laws and regulations in place to control and steer the industry.

**Challenges in Sustainable Production in Indian Tea Industry**

As Nidumolu et al observe in Why Sustainability Is Now the Key Driver of Innovation[3]; many of the corporate managers, both in the USA and Europe believe that making their operations sustainable and developing green products put them at a disadvantage vis a vis their rivals in developing countries where they do not feel such pressure. That challenge is nowhere clearer than in the case of the tea industry which, as illustrated by figure 2, is dominated by emerging economies of China and India followed by Kenya, Sri Lanka and Vietnam. The world is cognizant of the lack of sustainability efforts of these countries as they slowly transition to market economy. In the tea sector, due to the structure of the industry and the spread- out supply chain with very little accountability built into the system, the challenges grow exponentially.
Lack of knowledge by smallholders of harmful effects of chemicals, pollution and aging tea bushes with different diseases only compound these problems.

![Major Producers of Global Tea](image)

**Fig.2 emerging economies that are major producers of tea in the world**

Many corporations have committed resources to market only sustainable tea by 2020. Even then it begs the very important question: what constitutes sustainable tea? Does it consist of better working condition and human rights protection for tea laborers or does it concern the environment? [12] The nature of the situation varies from country to country. In India, the problem mainly revolves around exploitation of the labor force in terms of payment and health facilities and working condition as well as the environmental sustainability. In Indian tea estates, fair wages, working hours and conditions, child care facilities, health care, protection against redundancy and women’s issues lie at the core of the sustainable production debate. According to a report published by the organization “Save the Children” in India, “due to poor socio-economic conditions, children generally start working in tea gardens at the tender age of 11 years.”[13] Additionally, malnutrition on tea estates is still a big problem which leads to all kinds of medical problems including, in some cases, infant death and starvation. Many plantation communities in these countries have inadequate access to basic facilities such as drinking water, sanitation and electricity.[10]

Sustainable tea production invariably leads to higher cost. Green production may not stand the test of authenticity as there are too many individual suppliers involved in the supply chain, mainly in the forms of small tea gardens who are some of the best quality producers in the field. The price paid by the agents of private processing factories or the BLF (Bought Leaf Factory)s to the small growers is based on the auction price fetched by some representative factories. The caveat is, there is no formal list of these “representative” factories and there are no disclosures made on how the price is determined. As a result, they have very little control over profit and even lesser incentives to make sustainability a focus of their production efforts. [5]
At the moment, most Corporations view sustainability not as a zero sum game, but rather a cost center. The impact of social costs in the larger estates turns out to be 5-8% of total cost. Labor costs comprise around 60% of the total costs. The profitability ratio of the industry at the current ratio, both in the domestic and international markets does not provide a way to meet these costs. [10] According to the latest available data on costs as available in a report by the Tea Board of India, social cost implies an additional Rs. 4.12 per kilo of manufactured tea in North east India and Rs. 3.44 per kilo in Southern India. [8] The smallholders, on the other hand do not have to bear the social costs. This overwhelming cost burden is resulting in major tea companies divesting their estates and tea garden is being used for other crops. It is also argued that many producers in other industries who often blame the suppliers for all ethical violations. Like many other industries involved in production in emerging economies, global brands in tea industry also try to pass on the costs of necessary improvements down the supply chain to their suppliers while claiming the benefits of these improvements as well as the commercial gains from their CSR position.

Tea plantations are also plagued by diseases and production and processing of tea often leads to degradation of soils, loss of biodiversity and excessive water use and also negatively affects tea workers. Additionally, the small tea sectors fail to address environmental issues. Large-scale conversion of forest land to tea cultivation, and measures to correct ecological imbalance and other environmental problems sometimes pose challenges to small growers.[10] The small tea growers segment is ill-equipped to address the social, economic and environmental responsibilities at the production level. It is important to empower this segment so that they can respond to the preferences of consumers who seek environmentally, socially and ethically superior products. Financial costs seem to be the most important constraints in the case of the small growers to fulfill such obligations.

Based on a 100 odd years old tradition of tea management, CSR and Sustainability issues are still viewed by big corporations as philanthropy alone. The following figure details the prevalent trends associated with sustainability issues in Indian Tea Industry.

<table>
<thead>
<tr>
<th>Corporations:</th>
<th>Growing commitment to sustainability, transition from a “Philanthropy only” mindset</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Tata Global: Rainforest Alliance/Ethical Tea Partnership</td>
</tr>
<tr>
<td></td>
<td>Hindustan Unilever: Rainforest Alliance/Partners in Change</td>
</tr>
<tr>
<td></td>
<td>Twinings : Sourced with Care</td>
</tr>
<tr>
<td>Small Growers</td>
<td>Perceives sustainable production as an added cost</td>
</tr>
<tr>
<td></td>
<td>Not sure how that differentiation has the potential to be a competitive advantage</td>
</tr>
<tr>
<td></td>
<td>Concerned regarding their share of responsibility in sustainable production in comparison to bigger estates</td>
</tr>
<tr>
<td>Tea Garden Laborers</td>
<td>No role in decision making process</td>
</tr>
<tr>
<td></td>
<td>Exploited for generations</td>
</tr>
<tr>
<td></td>
<td>Reveres nature from a religious point of view, not necessarily from sustainability standpoint</td>
</tr>
</tbody>
</table>
Challenges of Sustainable Consumption in Indian Tea Industry

The individual consumer’s situational analysis:

Tea buying is a low-involvement purchase. Though data suggests that there is a tendency towards obliteration of boundaries in mass consumption patterns, differences still abound. That chasm is more prominent in scope in the area of sustainable consumption. According to the Future of Tea Report, “implementing sustainable measures at the production end is not enough over the longer term to deliver a sustainable value chain. Consumers need to be brought on the journey so that they develop a greater understanding of where their tea comes from, who produces it, how it’s produced and how it reaches them. They need to value tea in social, environmental and economic terms, and by doing so support sustainable production.”[6]

The report also states that the concept of “quality” and the understanding of sustainable tea have not yet fully emerged and tea is still viewed by many as a cheap commodity. The report further suggests sustainable consumption ideally must include a tea consumer’s ability to appreciate and understand the economic conditions of the tea industry and the supply chain. [6] This proposition may be compared to chasing a phantom market in emerging economies. There is distinction in everyday aspects of life that is manifested in one’s interactions with others, how and which resources they struggle for, the aesthetic tastes that they exhibit, activities they engage in and the products they consume. To conceptualize these variables for discussion purposes, I label them as means, motives and consequences.

Customer engagement towards sustainability issues is one of the biggest challenges in the domestic tea market in India. The 2030 forum report refers to consumer engagement as an effort “so that they both demand more sustainable tea and reduce impacts associated with tea consumption.” [8] “Green consumption is mainly defined in relation to eco-efficient production, representing an end-of-pipe approach in which consumer should be persuaded, incentivized or ‘nudged’ to buy green products. [1] But since the market force is tilted in case of the Indian tea industry towards local consumption, it is imperative that the means, motives and consequences of tea consumption of Western tea consumers and the domestic Indian consumers are addressed within proper contextuality. Whether green consumption is a possibility across the span of both Western and Indian domestic consumers is addressed in detail below.

Means: There is manifested disparity in spending capabilities of tea consumers across the world. Consumer demand for goods and services depend on both their ability and willingness to buy a certain product. There are many ways to spend money and there is also a wide gulf between those who have it and those who don’t. That is a key driver in all consumer decision making processes. Demand for necessities remain stable over time in lower-income strata of the society.
Though 80% of the tea produced in India is consumed locally, the bulk of the tea (60%) is consumed in the form of loose tea by the low-income consumers. [5] There are 6.6 billion consumers in the world; only 1.5 billion of them possess purchasing power greater than $10,000. The other 5.1 billion people- 78 percent of the global population are low-income consumers. The Rural Indian Base of the Pyramid (BoP) market is defined as households in the bottom four expenditure quintiles (based on data from the National Sample Survey Organization, India) that spend less than Rs. 3,453 Indian rupees (US$75) on goods and services per month. This definition represents a market of 114 million households, or 76 percent of the total rural population. [15]

The average price for loose tea in Indian market is around Rs.130 per kilogram, roughly a dollar a pound. According to data obtained from Statista, an average consumer consumes less than a pound of tea in a year. On the other hand, in UK, e.g. the average cost of basic blended Indian loose leaf tea is around $40 dollars a lb. with a possibility of exotic India tea price reaching upwards of $120 a pound. Even at that price, an average consumer consumes more than 3 lbs. of tea a year. Bigger spending capability indicates that consumers are generally more discerning and exhibit tendencies to be more concerned about the ethicality or sustainability of products in use.

Motives: A survey conducted on consumer’s response to socially responsible and environmentally friendly tea in India demonstrates that consumers displayed a low level of involvement with the social and environmental issues in the food and beverage industry. [5]. In a study done by Paul C. Henry that looked at social class and how it relates to consumers’ feelings of empowerment suggests that lower-class consumers aren’t likely to feel that they have the power to affect outcomes. [16] Henry identifies two groups that he calls potent actors (those who believe that they have the ability to take actions that affect their world) to impotent reactors (those who feel that they are at the mercy of their economic situations). In contrast to the affluent and hence empowered western consumers of tea; the majority of domestic consumers in India are characterized by a constrained financial position and a lower status evaluation and appear to be (dis)empowered.

To elaborate, there is no interface between producers and retailers and this influences the quality of tea. It is reported that adulterated tea in local markets push down the demand for quality tea and it may harmful to health as well. Consumers may not avail and access quality tea and what they are offered is mostly based on the retailer’s preferences. Yet, due to their abysmal financial situation, the consumers are either unaware or too reluctant to demand quality produces or question the sustainability issues in the value chain. On the other hand, the western consumers are willing and able to pay a higher price and, therefore, demand sustainable products and can and do exert influence and demand higher standard. This is one of the reasons why most Non Profit Organizations who represent the consumer interest are found in Europe and America. This phenomenon can be summed up as income-social responsibility paradigm where it is often demonstrated that sustainability mindset is directly proportionate to income.

It is established that culture plays a significant role in purchase motivation. A range of conceptual work has framed ethical consumption through the lenses of lifestyle in order to explore how concerns with, for example, well-being of the planet can be conjoined with concerns for the self in alternative consumption discourses. [17] Different cultures, depending on their
norms and value system and rituals, consume tea in different settings and seek different outcomes. In countries such as India, tea drinking is a social occasion. In a very preliminary survey conducted amongst Indian tea drinkers, 100% of the 23 respondents answered that never drink tea alone. In collectivistic societies, ceremonial social tea drinking ritual itself becomes more important than the product itself. In contrast, in individualistic societies the type of benefit sought from tea becomes more important. The majority of the tea drinkers in India can be labeled as apathetic to the issues of sourcing as they are unable to care much about whether the environment is affected adversely in tea growing efforts or about the working conditions of the tea garden laborers.

**Consequence:** As a result of limited financial resources, we see that India’s per capita tea consumption for the year 2016 is less than a pound at an average of .72 pounds. This statistics is a clear indicator of the fact that though the bottom of the pyramid tea consumers of India wield a collective power over the tea market locally, their individual consumption rate is near negligible. In the loose tea market in India, very often, various levels of adulteration are prevalent which is done by the retailers mainly to increase their profit from the ‘original’ tea. Generally, retailers prefer tea with which they can make good profit and they are not sensitive about the social and economic responsibilities issues in tea gardens. There is no interface between producers and retailers. However, retailers play a major role in deciding consumers’ tastes and preferences especially in rural markets. [10]

<table>
<thead>
<tr>
<th>Means</th>
<th>Motives</th>
<th>Consequence</th>
</tr>
</thead>
</table>
| **International Consumers** | - Rich, able to pay higher price  
- Access to quality products | - Aware of the long-run impact of sustainability, particularly on the environment  
- Believes in a cause, viz. helping the laborers and the environment  
- Tea drinking mostly is an individual ritual, allowing one to focus on the product itself | - High consumption rate  
- More discerning buyers, able to exert pressure on the corporations |
| **Domestic Consumers** | - Constrained by lack of spending power  
- Available product quality mostly poor and adulterated | - Majority apathetic towards such issues, feels (dis)empowered  
- Drinking tea is a social, collectivistic ritual | - An insider’s perspective  
- Low consumption rate |

Note: Points to empirically discernably different tendencies located among two groups of consumers

**Fig.4 Variables that affect means, motives and the consequences of international and domestic tea buyers**

**Implications for Big Corporations**
The steady yet increasing pressure from the wealthy consumers of the world, coupled with the marketing differentiation sustainability allows for brands, have influenced the most notable three tea corporations: Hindustan Unilever, Tata Global Beverages and Twinings to commit themselves to sustainability in Tea Industry. Tea industry in India is 100 years old with management style and culture that was drawn upon a colonial mentality. Till not long ago, Corporate Social Responsibility (CSR) was often equated with philanthropy. Tea was grown, procured from and packaged and sold without allusions to profit and not much to the planet and the society. But the greater demands from non-profit organizations and consumers have influenced these corporations to change their courses. Corporations usually take a reactive approach to development where they follow opportunities in market. Tea estates display a social hierarchy that is clearly a legacy of British colonialism and the tea laborers are treated with very little respect and dignity. In recent years that trend has been somewhat shifting towards a more shared value centric approach in which corporations are interacting closely with the community in which they operate with a duel approach of enhancing competitive advantage while contributing to the betterment of society. The major three corporations in discussion in this paper are aware of the limitations of the other players in the value chain and are responding accordingly.

Unilever is a key player in convening Tea 2030 with Forum for the Future [6] with focuses on three areas: sustainable landscapes, market mechanisms and engaging consumers. In 2013, Unilever helped to establish trustea, the Indian tea industry collaboration on sustainability. The trustea logo guarantees the social, economic, agronomic and environmental performance of Indian tea estates, smallholders and ‘bought leaf factories’ - factories that buy tea from multiple sources. The initiative covers over 600 tea factories (BLF) and will impact 40,000 smallholders and 500,000 tea estate workers. According to the corporate website, till date, 398 tea estates have been certified as sustainable estates by Rainforest Alliance and trustea in India. In 2015 alone, 181 tea estates across Assam, West Bengal, Kerala and Tamil Nadu were certified as ‘Sustainable Estates'. In 2015, over 28% of tea was sourced from sustainable sources in India for Unilever's brands. [18]

Tata Global Beverages is committed to be the most admired natural beverage company in the world by making a big and lasting difference through Sustainability and Corporate Social Responsibility. Tata wants to achieve it “by being the consumer’s first choice in sustainable beverage production and consumption.”[19]

Twinings states they are already aiming to buy from the best estates, both in terms of quality and ethics, but admits that even these can be improved further, which is what they aim to do. Their Sourced with Care programme is designed to help support the changes needed to make “this reality in the places around the world where we source our goods and ingredients.”[20]

As discussed above, the main challenge for these corporations in terms of SCP in the industry is twofold. In the production side, reliance upon smallholders constricts their ability to successfully source only sustainable products. On the consumption side, in absence of a knowledgeable and demanding market force, the suppliers can ignore the issue. Therefore, the onus lies on the corporations to “enhance the consumer uptake of eco innovations by fostering environmental consciousness and encouraging consumers to choose “green” products from market-place, whether by offering market incentives or penalties (through preferential pricing
strategies for greener products) or appealing to their attitudes through information and marketing campaigns”[1] only. Their targeted market segment is LOHAS demography. Research suggests that positive attitude towards sustainability always necessarily ensure purchase of sustainable products. But apathy of the majority of the consumers towards sustainable products has a far reaching consequence down the value stream. This translates into a potential dearth of excellent quality supply even at a high price. This leads to the conclusion that marketing sustainable tea to the Base of the Pyramid buyers in India is not a valid proposition. As a result, Unilever, Tata Global and Twinings- all seem to be embracing the “reality that high margins and price points aren’t just a top-of-the-pyramid phenomenon; they’re also a necessity for ensuring sustainable businesses at the bottom of the pyramid”[21]

**Conclusion**

The tea industry has been a neglected industry for a long period where specific preferences in specific regions of the world dictated production and consumption and consequently demand patterns. Sustainable Consumption and Production (SCP) has become a key focus for the industry only in the last 10 years or so, mainly due to the concerted efforts of a few major nonprofit organizations based in Europe. Sustainability efforts, particularly in the food and drinks industry are cost-intensive. Consequently, consumer demand appears to be an efficient way to exert a reformatory pressure on the big corporations. But a dichotomy arises when majority of the consumers are unaware of traditional sustainability issues in a market. Consumer perceptions and preferences differ markedly among age, income, occupational, cultural, and lifestyle components of the consumer population. Like other emerging economies, in India focus on sustainable consumption and production is directly proportional to income and social class. For the Base of the Pyramid tea consumers, financial restrictions result in apathy towards the plight of the workers in the tea gardens and environmental degradation. The means, motives and consequences of their purchase are markedly different from concerned and knowledgeable Western consumers. That is the underlying reason why SCP focus in tea industry is an outside in focus.

On the production side, Indian tea industry is comprised of multitude of smallholders and Bought Leaf Factories (BLF) who are not financially, technically or informationally adequately prepared to address sustainability issues. In spite of limited and declining export opportunities for Indian tea, the big three corporations who are involved in branding and packaging are trying to manipulate their resources to address the sustainability issues and are working towards it. The biggest challenge for them is to mobilize the smallholders and remain competitive without looking into other tea producing countries where sustainability may have a greater inspiration amongst suppliers.

Looking ahead on the SCP trend, it may be reasoned that on the production side, smallholders must be provided with adequate knowledge of sustainability. They will also benefit from direct knowledge transfer on sustainability and not simply from certification mandates from the corporate buyers and the governments. Shifting attitudes then may result in shifting behavior. On the consumer side, sustainable consumption may remain an elusive proposition for the majority of the tea consumers in India given their economic situation. Consumer engagement must be addressed, yet again, in terms of enhanced awareness. It will be a while before
sustainability strategy imperative will be systematized and integrated into the day-to-day practices of firms of all sizes in tea industry in India.

References:


Trans-Pacific Partnership: Opportunities and Problems
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Abstract

Trans-Pacific Partnership (TPP) has been the focus of numerous debates and discussions since the partnership was announced. This partnership is to be among several countries in Americas: U.S., Canada, Mexico, Chile, and Peru and South Pacific: Brunei, Malaysia, Singapore, Vietnam, Japan, Australia, and New Zealand. The first part of this research examines the opportunities this trade pact among such diverse group of partners can create: Enforcement of labor rights, benefits to small businesses, and increased markets for different products. The second part of the research investigates the negative impacts of such partnership: Relocation of companies and jobs to low-cost labor partners, enforcement of patents such as pharmaceuticals that increases the cost of drugs and medications in poorer partner countries in addition to opening these market to unsafe products. The last part of the research concentrates on how TPP can be improved to create a true sustainable partnership for the members specifically the ones with an emerging economy.
Big Data Intrusion Detection Analysis with PySpark and GPU Acceleration

Abstract:

This paper explores the potential of applying Apache PySpark big data analytics API in an advanced network security/forensics class to teach intrusion detection analytics and further compare the performance of CPU and GPU in processing. Related technologies are discussed for the conceptual coverage, efficiency and effectiveness of the experimental design. Both supervised and unsupervised machine learning algorithms are introduced to perform the analytics. Students will be able to learn from practical viewpoints the technology applied in the industry.

Keywords: network security, intrusion detection, machine learning, analytics.

1. Introduction:

Intrusion detection is an important information security application of data analytics. By analyzing the patterns of numerous data fields in network packets, intrusion detection system (IDS) can either match the network traffic with a known attack signature (misuse detection) or detect abnormal behaviors (anomaly detection). Both require machine-learning artificial intelligence, hence is a challenge in teaching advanced network security courses.

Apache Spark, originated at the UC Berkley AMPLab, is an open source framework for distributing programs across clusters of machines. It is a significant advancement over its predecessor, MapReduce, in several ways. Firstly, it can follow the execution flow of a General Directed Acyclic Graph (DAG) instead of a sequential map-then-reduce order in Hadoop MapReduce. This enables it to write immediate results out to the distributed file system. Secondly, it has a strong developer focus and streamlined API which enables programming more naturally. Thirdly, Spark has improved in-memory processing based on its Resilient Distributed Dataset (RDD) which holds the processing pipeline in memory across the cluster. [6] This significantly reduces the revisit of the file system for large dataset and hence improves the execution time.

PySpark is the Python API of the Spark platform. PySpark allows for full Spark utilization without writing any non-python code or multiple command line calls like with Hadoop Streaming. Besides, Spark has full access to python's 67,000 packages [7].

Even though Spark is designed for big data analysis of TBs and over large-scale computing clusters, its strengths are also significant over close to analyzing GB or even less data over a multi-core PC or server. Hence teaching the subject of intrusion detection by machine learning in Spark has multiple benefits:

1. A smoother learning curve due to the streamlined API.
2. Industrial standard technology which is cutting-edge and practical.
3. Reduced experimental time.
4. Support of multiple machine learning algorithms that are either supervised or unsupervised.

NVidia CUDA (Compute Unified Device Architecture) allows GPUs to perform large scale parallel computing very efficiently due to the large number of simple cores and the shared video memory. The performance gain is more significant with the machine learning workload increase, which can be parallel accelerated by large amount of CUDA cores.

2. Experimental Environment:

The Apache Spark environment applied is running over a HashiCorp Vagrant in an Oracle VirtualBox. Vagrant is open-source software which provides a method for creating repeatable development environments across a range of operating systems. The reproducible provisioning script is simply stored so the students only have to download a Vagrant file to configure their entire development environment [2]. The Jupyter Notebook is a web-based Python IDE of which the Anaconda Python kernel is also provisioned with the Vagrant virtualbox. Hence the students only need to perform minimal amount of installation and configuration before they will start hands-on experiments with PySpark programming. The particular laptop in the following experiment has an Intel Core i-7 quad core 2.9GHz Lenovo laptop running Windows 8.1 x64.

The GPU acceleration experiment is completed on an Ubuntu Linux 14.04 desktop with an NVidia GeForce GTX 950 video card with 1024 CUDA cores. The desktop has an Intel Core i-5 quad core 3.2GHz CPU which has a performance comparable with the laptop CPU. The Spark-GPU prototype [4] enables this GPU/CPU big data analysis performance comparison.

The network data is from the KDD CUP 99 [1], which is a very popular and widely used intrusion attack dataset. The full dataset has over 4.8 million records, 41 feature fields with 23 types of intrusions in the labeled dataset. The detailed description of the available features and attack instances can be found in [5].

3. Machine Learning Algorithms for Intrusion Detection:

Python Scikit-learn is popular in machine learning which is designed for single-CPU, while Spark MLlib (Machine Learning Library) is for designed for scaling to a distributed cluster. Spark 1.6.1 supported a number of machine learning algorithms [3]. In order to teach both supervised and unsupervised machine learning applications in network intrusion detection, two algorithms are selected for comparison: for supervised learning, logistic regression with L-BFGS; for unsupervised learning, k-means clustering.

3.1. Supervised Learning Example:

Supervised learning is the machine learning task of inferring a function from labeled training data. Logistic regression (a.k.a. logit) is widely used to predict a binary response, which are attack or normal packet types in the network intrusion detection application. The logistic regression can be understood as finding the $\beta$ parameters that best fit:

$$y = 1, \beta_0 + \beta_1 x + \epsilon > 0$$
$$y = 0, \text{otherwise}$$
where $\epsilon$ is a small constant. L-BFGS is an optimization algorithm in the family of quasi-Newton methods. Hence the selected supervised machine learning algorithm is named as LogisticRegressionWithLBFGS in pyspark.mllib.classification library.

1. **Data Preparation:** Since logistic regression performs binary classification, we will tag each network interaction as non-attack (i.e. 'normal' tag) or attack (i.e. anything else but 'normal'). The training data and the test data are then mapped separately to Spark’s Resilient Distributed Dataset (RDD) and made persistent, which will keep the datasets in memory to accelerate revisits.

2. **Training:** Training on the laptop CPU takes about 368 seconds over the full KDD-99 dataset of over 4.8 million records. This is a significant improvement over single-CPU machine learning tools that does not parallelize the learning, which often takes too long and students thought that the program is simply frozen. In earlier practice, the 10 percent KDD-99 data had to be used instead.

3. **Testing:** The testing dataset is over 300k records. The prediction time is about 14 seconds and the test accuracy is 0.9164.

4. **Evaluation:** The MLlib evaluation package is applied to perform the binary classification evaluation. The two key evaluation benchmarks are: the area under ROC (Receiver Operating Characteristic) which is 0.966; the area under PRC (Precision-Recall Curve) which is 0.992.

5. **GPU Acceleration:** GPU acceleration on 1024 CUDA cores is obvious. The same training task takes only 270 seconds on GPU. The same test task takes slightly less time, 13.059 seconds. Both CPU and GPU give exactly the same accuracy, ROC and PRC values as expected.

3.2. **Unsupervised Learning Example:**

Supervised learning with labeled data delivers high accuracy in prediction. However, in practice, labeling the network data for training the model is very expensive, hence unsupervised learning must be discussed for the students to have a full understanding of the design of IDS which combines both the supervised learning and unsupervised learning. This combination generates multiple models for pattern matching to reduce the undetected network intrusions. Unsupervised learning is the machine learning task of inferring a function to describe hidden structure from unlabeled data. Since the examples given to the learner are unlabeled, there is no error or reward signal to evaluate a potential solution. Models vary in parameter settings are compared and a best model is selected.

K-means clustering is one of the most popular unsupervised learning algorithm. The problem is computationally difficult (NP-hard). The k-means algorithm can be understood as finding the minimal distance of a vector ($x$) to a number of $k$ centers ($\mu_i$) to classify it:

$$\text{argmin} \sum_{i=1}^{k} \sum_{x \in S_i} ||x - \mu_i||^2$$
Euclidean distances are calculated and passed to the KMeans class of the 
pyspark.mllib.clustering library with a random initialization.

1. **Data Preparation:** K-means works with numeric features. Hence, the non-numeric 
   features are excluded. Due to the calculation complexity of the algorithm, it is not practical 
   to conduct the clustering over a dataset of over 4.8 million records on a quad-core CPU. 
   Therefore, the previous test dataset of 300k is applied for clustering. The previous training 
   dataset and test dataset are otherwise equivalent in structure. Numeric data is also 
   standardized before passed to the k-means clustering.

2. **Clustering:** Since the number of $k$ centers is unknown, there is another optimization of $k$ 
   that must be conducted before the final best model is selected. Again, this process takes 
   at least hundreds of seconds before parallelized by Spark on multi-processors which 
   actually took about 42 seconds on the experimental laptop and the optimal number of 
   clusters is 10 (hence 10 types of attacks classified without referring to their labels) with 
   the clustering score of 0.8116.

3. **GPU Acceleration:** GPU acceleration on 1024 CUDA cores makes a fundamental 
   difference in unsupervised learning which is more processor-intensive. The full KDD99 
   dataset (4.8 million records) can be standardized in 6.753 seconds, clustered in merely 
   27.869 seconds with the optimal number of 10, and a clustering score of 1.026064.

4. **Conclusion:**
   
   This paper has conducted experimental design for Python programming projects over Apache 
   Spark in an advanced network security class to introduce network intrusion detection methods. 
   The projects’ design is hands-on, efficient as well as practical. Students will learn within limited 
   class and assignment time the principles of supervised and unsupervised machine learning 
   algorithms, their application in intrusion detection analytics. Moreover, the experiments can be 
   conducted over a relatively large, popular network intrusion dataset and completed over their 
   laptops. The same Python code can be executed on a Spark GPU prototype for parallel acceleration. 
   The skills they learn will be highly transferable to their future career because of the high demand 
   of data analytics skills, especially big data analytics skills. Future work will continue to explore 
   the accommodation of other machine learning algorithms from the MLlib for network intrusion 
   detection, or applying PySpark to other courses with larger data analytics technology requirements.

**References:**

[1] KDD99-cup, the Third International Knowledge Discovery and Data Mining Tools 


Complementing Database Design for Microsoft Access with MySQL Workbench

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Abstract
Microsoft Access is a popular computer program used to teach database design, development and applications in many business curricula. Students learn how to develop database tables and their relationships. They also learn how to populate the tables with data, using forms, generate cool reports, and develop quite sophisticated queries. More advanced topics get them into application development, using VBA. Consequently, they can appreciate lots of appealing features and tools offered by Access. Unfortunately, Access has a very weak point. It has insufficient support for one of the most important steps of the database life cycle: the logical data design. Yes, database experts, having a good understanding of the business context, can design databases by sketching logical data model [mentally] and going straight into developing a physical designs. Such experts also understand that a logical data model is the most critical task and, if well done, it will lead to a robust physical design. They also recognize that, in general, logical data models are developed by interdisciplinary teams, including subject-matter experts and end-users who do not necessarily have a good understating of the database jargon, requirements and restrictions. Thus, in order to complete the logical phase of the database design, the teams opt for working with less intimidating languages and tools, including more intuitive graphical/visual tools. This paper shows how to fill the Access’s “logical gap”, using MySQL Workbench. It uses a simple example of a data model expressed in UML and implemented in the Workbench. The model is then used to automatically generate an SQL schema. Finally, it gets to the physical design by executing the schema, using the SQL Query tool in Access. This approach results in a database, consisting of proper tables and relationships without requiring any additional steps.

Keywords: database, design, logical data model, table, relationship, query.

LOGICAL DATA MODEL FOR A RELATIONAL DATABASE

A database can be developed in many different ways. An experienced database developer, having a good grasp of the business specifications (including requirements, rules and constraints) can get right to the physical design using SQL or table and relationship building tools (all available in Access). Such an expert can usually get by without a logical data model or s/he can visualize the model without using any special (automatic) tools.

Mere mortals or those dealing with complex data structures have to work harder. In general, even if one believes that the logical model is not necessary, the analysis of the business side of the
design can contribute to better results. In many situations, getting a correct result depends decisively on accurate interpretation of business requirements and rules.

A classical approach to the database design involves three levels or views: external, conceptual and internal (Date, 2000, p. 33). The design process consists of several phases such as requirement analysis, conceptual (high level) design, and logical design—all leading to a physical design (Elmasri, et al., 2004, p. 51). This paper shows how to build a logical data model that is a combination of the conceptual and extremal views, resulting from the business requirement analysis. The model includes a complete set of entities, attributes, keys, relationships, cardinality and participation constraints that are necessary to accurately define a physical database (Silberschatz, et al., 2001, p. 27-37). It is structured as an Enhanced Entity Relationship Diagram (EERD), using MySQL Workbench. Such a model can be automatically transformed into a physical design (database schema) expressed in SQL (Letkowski, 2014).

In many situations, successful development of an ERD data model, using systems like MySQL Workbench, depends more on the business domain expertise than on the database skills. A subject-matter expert, who understands simple concepts of an entity (or class), instance (object) and relationship can decidedly contribute to development of the data model.

PROBLEM SPECIFICATIONS

Nick is a Web developer, who wants to run a Web site, hobbysta.org, specializing in sharing information among hobby enthusiasts all over the World. He asked Karolina, a teacher at a local business college, to design a prototype database in Access so that he could easily experiment with the database before integrating it with his Web site. Nick understands that his target database server will be MySQL or a similar database system, but he loves the QBE environment for experimenting with all kinds of queries that might be later used by his Web applications. He wants to start with a simple database that would allow for member registration and hobby selection. He wants to develop and maintain a logical data model that would be flexible enough to accommodate future expansions. To get started, he wants only simple information about members (given name, family name, and email) and hobbies (hobby title and short description). Karolina decided to get some help from her student, Emma, majoring in Entertainment Management. Emma does not have any database background, beyond what she learned in her spreadsheet class.

HIGH LEVEL DATA MODEL

The entire process of the database design is presented below in from of discussion among three individuals: Nick, Karolina, and Emma. The author of this paper (Author) provides additional comments.
**Karolina**: Having learned about Nick’s situation, I recommend to develop a logical data model and to generate an SQL schema, using MySQL Workbench. The resulting schema will be very close to what Access needs in order to create tables and relationships. Before delving into painting the logical model, I want to verify my understanding of the Nick’s specifications by writing short, but precise, English statements that will describe and bind members and hobbies. I suppose, a member can have at least one hobby and a hobby can be enjoyed by one or by many members. Actually, we should relax the strict requirements and allow for storing member records even if they do not have hobby and to have hobbies that are not involved with any member. Let use names Member and Hobby to represent collections of members and hobbies, respectively. At the initial (or high) level of the database design process, we refer to such names as entities or classes. Thus we have entity Member, a set of member records, and entity Hobby, a set of hobby records.

**Nick**: I am impressed. This is exactly what he had in mind. However, I do not fully understand that there could be hobbies not associated with any members and vice versa.

**Emma**: So do I!

**Karolina**: OK, supposed that you add a member who has a unique hobby (not picked by any other member). What do you want to do if the member quits. Do you want to also remove the hobby, or you want to keep it so that when another member picks the hobby, it will be right there among all the elements of the Hobby set? Another possible situation, would be to add the most popular hobbies to entity Hobby so that they would be ready to be selected by the members. This should simplify Web interfaces and minimize errors. Obviously, members will be able to pick additional (new) hobbies at any time. There may be also situations when a member wants to register with hobbysta.org but s/he prefers to pick a hobby or hobbies later. Finally, if we do not want to delete the record of a member who has dropped all her/his hobbies, then we should allow for the record to exist without connection to any hobby.

**Author**: They all agreed that an initial list (set) of the popular hobbies would be an excellent choice. It has also become clearer why we should allow for existence of orphan members and/or hobbies.

**Karolina**: Let me also explain why we are dealing here [initially] with two data entities: Member and Hobby. They are simply sets of objects (members and hobbies, respectively). A good practice is to name entities, using singular nouns written in a title case. To refer to instances of the entities we use a lower case. Thus members constitute the Member set and hobbies—the Hobby set. By the way, entities are also referred to as classes and instances as objects (as in object-oriented systems). To distinguish entities and their instances from other things, from now on, we will write them, using Currier fonts.

**Author**: Since there has been no database term used, Nick and especially Emma could follow everything so far.
Karolina: Emma, why don’t you prepare instance samples of the entities, for example, in a spreadsheet (Excel). In the meantime, let me wrap their discussion and analysis in a more formal way, using an annotated SUBJECT + PREDICATE + OBJECT format:

\[
\text{Member}(0..*) \text{ - has - (0..*)Hobby}
\]

What it means is that a given member (instance of set Member) can have zero, one, or more (0..*) hobbies and a given hobby (instance of set Hobby) can be selected by zero, one, or many members (0..*).

Emma: When you say it, it is all clear to me but if you wanted me to repeat it, I would have a hard time expressing exactly the same thing.

Karolina: Well, this is exactly what I suggested before but expressed in a more concise and crisp way. Let me try to explain it graphically (Figure 1). Bubbles represent objects (instances of the entities) and oval rectangles—sets of the objects (entities). Arrows connect (associate) Member bubbles with some Hobby bubbles. For simplicity, members are identified by their first names and hobbies—by their titles (other attributes are hidden). Don and Tom (instances of entity Member) have just one (1) hobby (collecting Golf Balls). Pat has two (*) hobbies (Golf Balls and Coke). Eve has three (*) hobbies (Golf Balls, Stamps and Coke). Golf Ball is picked by three (*) members (Don, Pat, and Eve). Both Coke and Stamps are selected by two (*) members (Pat, Eve and Eve, Tom, respectively). Post Cards (a hobby for collecting Post Cards) and Kim are an orphan objects. No member has picked this hobby. Thus it is associated with no (0) members. Similarly, member Kim has not selected any hobby. This it is associated with no (0) hobbies. Notice that the asterisks shown above denote many instances.

Figure 1  Entities, their instances and relationships.

Since there exist associations to many (*) instances on both sides (Member and Hobby), the relationship between entities Member and Hobby is referred to as a many-to-many relationship.
relationship. Such a relationship is not database friendly. It requires at least one extra [associative] entity to be placed between entity Member and entity Hobby but let’s learn more about the nature of our data model before we can resolve this complex relationship.

**Karolina** (continuing): I can see that **Emma** has not wasted her time. She captured the above entities and their instances in Excel (Table 1).

**Table 1 Initial sample data for entities Member and Hobby.**

<table>
<thead>
<tr>
<th>Member</th>
<th>Hobby</th>
</tr>
</thead>
<tbody>
<tr>
<td>givenName</td>
<td>familyName</td>
</tr>
<tr>
<td>Pat</td>
<td>Pacyk</td>
</tr>
<tr>
<td>Don</td>
<td>Donski</td>
</tr>
<tr>
<td>Eve</td>
<td>Evening</td>
</tr>
<tr>
<td>Tom</td>
<td>Tomas</td>
</tr>
<tr>
<td>Kim</td>
<td>Kimura</td>
</tr>
</tbody>
</table>

Each bubble shown in Figure 1 in now represented by one row in the above tables. Woops, I said it but I am not supposed to say it, not yet. **Table** is a database term and we are not supposed to use it until we get to the physical design. We are still developing a logical model. Nonetheless, **table** is a popular term and it will help us move forward with two important issues that must be resolved. The first deals with the so called entity integrity and the second one—with the many-to-many relationship. The entity integrity requires that each entity instance be unique. Each entity must have one or more attributes that uniquely identify each of its instances. Such an attribute or a combination of attributes is referred to as a candidate key. Since there may be more than one candidate key, the one that we choose for operational purpose is call a primary key. If there is no natural and/or convenient primary key, we can create an artificial one, a surrogate key. Traditionally (and also because of efficiency) the best primary (surrogate) keys have values taken from natural numbers (1, 2, 3, ...). They are the Integer type.

**Emma:** I get it. Let me add those keys to my Excel tables. Should I add them as the left-most columns?

**Karolina:** Yes, and name them mid and hid (for member ID and hobby ID). As you edit the tables, why don't you also try to reflect the relationships shown in Figure 1?

**Emma** (after a few minutes): I did my best (Table 2).

**Karolina:** You took care of the entity integrity brilliantly but, unfortunately, the memHobby attribute show the relationships correctly but it is not relationally acceptable. All relational entities must have single valued (atomic) attributes. This requirement (as related to database tables) is reinforced by a database normalization rule, the so called First Normal Form (Date,
2000, p. 127). We could fix this problem right in Excel, but it will be easier and more professionally to do it in MySQL Workbench.

**Table 2 Revised tables (entities) Member and Hobby.**

<table>
<thead>
<tr>
<th>Member</th>
<th>mid</th>
<th>givenName</th>
<th>familyName</th>
<th>email</th>
<th>memHobby</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pat</td>
<td>Patyka</td>
<td></td>
<td><a href="mailto:pp@hobbysta.org">pp@hobbysta.org</a></td>
<td>1.2</td>
</tr>
<tr>
<td>2</td>
<td>Don</td>
<td>Domski</td>
<td></td>
<td><a href="mailto:dd@hobbysta.org">dd@hobbysta.org</a></td>
<td>1</td>
</tr>
<tr>
<td>3</td>
<td>Eve</td>
<td>Evening</td>
<td></td>
<td><a href="mailto:ee@hobbysta.org">ee@hobbysta.org</a></td>
<td>1,2,4</td>
</tr>
<tr>
<td>4</td>
<td>Tom</td>
<td>Tomas</td>
<td></td>
<td><a href="mailto:tt@hobbysta.org">tt@hobbysta.org</a></td>
<td>4</td>
</tr>
<tr>
<td>5</td>
<td>Ken</td>
<td>Kimura</td>
<td></td>
<td><a href="mailto:kk@hobbysta.org">kk@hobbysta.org</a></td>
<td>0</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Hobby</th>
<th>hid</th>
<th>title</th>
<th>description</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Golf Balls</td>
<td>Collect golf balls.</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Coke</td>
<td>Coca Cola memorabilia.</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Post Cards</td>
<td>Collect post cards.</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Stamps</td>
<td>Collect postage stamps.</td>
<td></td>
</tr>
</tbody>
</table>

We will start with two entities, **Member** and **Hobby**, having attributes shown in Table 2 except of the **memHobby** one. As mentioned, these entities are part of the high-level model expresses as:

**Member \((0..*) - \text{has} - (0..*)\text{Hobby}**.

**Author**: Because of a limited space, this paper only shows outcomes of major steps performed with MySQL Workbench and later with Access. For detail instructions, consult the resource page specifically developed to complement this paper (Letkowski, 2016).

**LOGICAL DATA MODEL**

**Karolina**: Our first job is to place on the canvas (diagram board) the two entities (tables): **Member** and **Hobby**. Next, we add attributes to the entities (Figure 2).

![Figure 2 Creating entities with attributes in MySQL Workbench.](image-url)
To this end, we use the **table** tool (or press T) and then click anywhere on the canvas. Next, we open the table’s property panel by double-clicking the table. This will allow us to change the name of the table, and add the attributes and specify their types. By default, MySQL Workbench defines the first attributes as Primary Key which is what we want in order to ensure the entity integrity. Of course, if one wants different keys, they can be manually redefined.

Notice that MySQL Workbench does not use term *entity*. Instead, the entities are referred to as *tables*. Still, the diagram is called EERD (Enhanced Entity Relationship Diagram) rather than ETRD (Enhance Table Relationship Diagram). I guess, we can live with this slight intrusion of the database jargon.

It is interesting to note that, if we were to do it in Access, the tables would have a very similar structure (Figure 3). However, we would not be able to directly bind the tables (create a relationship) since Access is unable to resolve [automatically] many-to-many relationships. Moreover, in Access, in addition to the primary key, *foreign keys* would have to be defined.

![Table Examples](image)

**Figure 3 Creating tables Member and Hobby in Access.**

**Emma:** I am not sure I understand. What is a foreign key?

**Karolina:** Well, I messed things up a little but I did it on purpose so you can see that going forward with the design in Access would require a higher level of the database expertise. I want to complete the logical design without those database buzzwords. Bear with me, you will soon see how foreign key are born and what they do.

**Emma:** This is quite suspenseful!

**Karolina:** I am glad you are having fun with this technical stuff. We are just one step from completing the logical design. All we need is to connect [in Workbench] the entities with a *many-to-many* relationship tool (Figure 4).

To this end, select (click) the many-to-many (\(n:m\)) button (on the tool bar), then connect the entities by clicking each one after another. Notice that the button shows a Craw’s Foot notation of the relationship. The diagram on the canvas uses an UML notation which can be set or changed via a menu command Model > Relationship Notation. By the way, I have been using different types of diagram formats in the past but I believe UML diagrams are the simplest and
most expressive. UML happens to be #1 choice for designing Object-Oriented (OO) applications. Since many database developers also develop applications, using Object-Oriented languages, it is convenient for them to express the model, using the Object-Oriented design language—UML (Naiburg, Maksimchuk, 2001).

As you can see, the three clicks have produced one extra entity (Member_has_Hobby) with two attributes annotated with a reddish icon ( ): Member_mid and Hobby_hid. Such an entity is referred to as an Associative entity. The entity’s attributes bind members (instances of entity Member) with his/her hobbies (instances of entity Hobby). Now, I can say it officially, these attributes are referred to a foreign keys and they are required to take on values of the corresponding primary keys, this way supporting the so called Referential Integrity. The lines, connecting the entities show the relationships graphically. They are kind of redundant since the relationships are already established by the foreign key and their related primary keys. On the other hand, the lines help to better visualize the relationships.

Figure 4 Add a many-to-many relationship in MySQL Workbench.

Emma: Wow, this is cool! I am impressed! By the way, I did identify the relationships but, unfortunately, in a wrong way.

Nick: I am impressed too! It is like having a Genie touch a magic wand and create something really beautiful.
**Karolina**: Indeed, it is like a magic and let me improve it a little by editing the new entity. First I recommend to change the name of the entity. Why don’t we name it `ActiveHobby` and change the attribute names to simply `mid` and `hid` (same as their related primary key names). These changes will make our future queries more clear and compacts. Do you think we should better describe the new entity? What about adding some extra attributes?

**Emma**: Two extra attributes come to my mind: the starting date and estimated annual budget of the members’ hobbies.

**Nick**: I was thinking about the starting date too.

**Karolina**: Great! Let’s add the two attributes named as `startDate` and `annualBudget`. Please notice that I consistently follow the OO naming convention (entities—in a title case, and attributes—starting with a lower case). We select a `DATE` type for `startDate` and a default `FLOAT` type for `annualBudget`.

**Nick**: What is the largest value that can be expressed, using the MySQL’s `FLOAT` type?

**Karolina**: A good question! Unless Mr. Elon Musk joins the site we should be OK with budgets up to $99,999,999,00. I you prefer a larger allowable maximum, we can select either `DOUBLE` (it defaults to the 16 significant digits and 4 decimal places) or `DECIMAL(m, d)` with sufficient number of significant digits ($m$) and decimal places ($d$).

**Emma**: I guess a `FLOAT` should work well.

**Nick**: Ditto!

**Karolina**: We can do it all by double-clicking the entity and making the changes in the table form (Figure 5).

It is also a good idea to annotate the relationship lines so that the diagram can be interpreted as a collection of S+P+O (Subject + Predicate + Object) statements. By the way, we can now express our original S+P+O model:

```
Member(0..*)-has-(0..*)Hobby
```

as:

```
Member(1)-has-(0..*)ActiveHobby(0..*)-involves-(1)Hobby.
```

This means that, if there exists an active hobby (an instance of entity `ActiveHobby`), it must belong to one and only one member (an instance of entity `Member`) and it also must involve exactly one hobby (an instance of entity `Hobby`). Going from the external entities, a member has zero, one or many active hobbies and a hobby gets involved in zero, one or many active hobbies. We need those zero constraints since there may be hobbies that are not chosen by any members and there may be members without any hobby.
Let’s do our final touches to our diagram (relationship annotation and their cardinality constraints). We will use the text tool to add labels the relationship lines.

As shown in Figure 6, you choose (click) the Text Object tool. Next, you click near the Member – ActiveHobby relationship line. MySQL Workbench adds a text box. You then double-click the box and change its name to [here] has. In a similar way, you add label involves to the second relationship.
Emma: I can now read the diagram as if it was written in English.

Nick: For me this is probably the best way to present a [rational] data model.

Karolina: Wait a moment, we are not done yet. We need to fix the cardinality constraints. At the ActiveHobby entity, we should have 0..* rather than 1..*. (Recall that we agreed that there may be members without hobbies and vice versa.) All we need is to double-click the relationship line, click the Foreign Key tab and uncheck box Mandatory (Figure 7).

Figure 7 Relaxing the 1..* cardinality constraint by making it optional (0..*).

We will get our final design, when we repeat this procedure for the involves relationship.

Figure 8 The final, relational data model.
FORWARD ENGINEERING

The logical data model is complete. MySQL Workbench refers to it as an enhanced model (EERD) since it can be used to generate a physical design (an SQL model) or to directly create the database and tables on MySQL Server.

**Emma:** Now what? What do we do with this gem? Can we now bring it to Access?

**Nick:** Yes, I can’t wait to see it in Access.

**Karolina:** Hold your horses! I wish Access could import databases from diagrams like this. Access has lots of importing power but not with this. However, Access can create tables directly from an SQL schema and MySQL Workbench can help us generate the schema. All we need is to invoke properly a menu service: Database > Forward Engineer (Ctrl+D) or File > Export > Forward Engineer SQL Create Script … (Shift+Ctrl+D). Let’s try the latter. A series of steps with some options set on (Omit Schema Qualifier in Object Names, Generate Separate CREATE INDEX Statements, Disable FK Checks for Inserts, and Export MySQL Table Objects) will lead to the following script:

```sql
CREATE TABLE IF NOT EXISTS `Member` (
  `mid` INT NOT NULL,
  `givenName` VARCHAR(32) NULL,
  `familyName` VARCHAR(64) NULL,
  `email` VARCHAR(128) NULL,
  PRIMARY KEY (`mid`))
ENGINE = InnoDB;

CREATE TABLE IF NOT EXISTS `Hobby` (
  `hid` INT NOT NULL,
  `title` VARCHAR(64) NULL,
  `description` TEXT NULL,
  PRIMARY KEY (`hid`))
ENGINE = InnoDB;

CREATE TABLE IF NOT EXISTS `ActiveHobby` (
  `mid` INT NOT NULL,
  `hid` INT NOT NULL,
  `startDate` DATE NULL,
  `annualBudget` FLOAT NULL,
  PRIMARY KEY (`mid`, `hid`),
  CONSTRAINT `fk_Member_has_Hobby_Member` 
    FOREIGN KEY (`mid`) 
    REFERENCES `Member` (`mid`) 
    ON DELETE NO ACTION 
    ON UPDATE NO ACTION,
  CONSTRAINT `fk_Member_has_Hobby_Hobby1` 
    FOREIGN KEY (`hid`) 
    REFERENCES `Hobby` (`hid`) 
    ON DELETE NO ACTION 
    ON UPDATE NO ACTION)
ENGINE = InnoDB;
```

**Code 1** The generated SQL script.
Emma: This is amazing: such a complicated code was created from our diagram. I have just one question. Could you explain why this procedure is called “Forward Engineer”?

Karolina: Certainly! In the database context, Forward Engineering is the process of transforming an ERD model into an executable SQL script (McLaughlin, 2013). A graphical model is transformed into an SQL model that can be used directly to develop a physical database. I would also consider MySQL Workbench to be a light-weight CASE tool, where CASE stands for Computer –Aided Software Engineering (Wikipedia, 2017). It captures quite a significant portion if the database life cycle and help in transition from the logical to physical design.

Nick: I also have a question. Can we run this script now in Access?

Karolina: We have a MySQL executable script but it will not work [directly] in Access. We need to get rid of a few pieces: ‘”’ (grave accent), ”ENGINE = InnoDB”, “IF NOT EXISTS”, “ON DELETE NO ACTION”, and “ON UPDATE NO ACTION”. They all can be eliminated in any text editor by using a Search and Replace command. To further simplify the script also segments “CONSTRAINT `fk_Member_has_Hobby_Member`” and “CONSTRAINT `fk_Member_has_Hobby_Hobby1`” can be removed. Such a cleanup will produce three statements that can be executed in Access’s SQL-Query panel:

```sql
CREATE TABLE Member (  
    mid INT NOT NULL,  
    givenName VARCHAR(32) NULL,  
    familyName VARCHAR(64) NULL,  
    email VARCHAR(128) NULL,  
    PRIMARY KEY (mid)  
);  
CREATE TABLE Hobby (  
    hid INT NOT NULL,  
    title VARCHAR(64) NULL,  
    description TEXT NULL,  
    PRIMARY KEY (hid)  
);  
CREATE TABLE ActiveHobby (  
    mid INT NOT NULL,  
    hid INT NOT NULL,  
    startDate DATE NULL,  
    annualBudget FLOAT NULL,  
    PRIMARY KEY (mid, hid),  
    FOREIGN KEY (mid) REFERENCES Member (mid),  
    FOREIGN KEY (hid) REFERENCES Hobby (hid)  
);  
```

Code 2 The simplified SQL script (meeting Access requirements).
CREATING THE TABLES IN ACCESS

Assuming an empty Access database (HobbyDB.accdb) is already open, the team led by Karolina will add tables and data to this database.

**Karolina**: If we started creation of the database in Access (as shown in Figure 3), we would have to physically add table ActiveHobby along with its primary and foreign keys. We would then open the Relationship diagram, add the three tables and connect the primary keys to their respective foreign key along with setting the referential integrity. Instead, we will use the SQL-Query panel and execute our CREATE TABLE statements, one at a time.

On the CREATE toolbar, select Query Design command, close the Show Table dialog window and select the SQL View option. Next, copy the first CREATE TABLE statement from (Code 2) and paste it into the Query tab. Finally, click the Run button to add this table to the database. The table should be show on the right, in the Navigation panel. Save the query as CreateTableMember (Figure 9).

![Figure 9 Add table Member to the Access database.](image)

Repeat this procedure for the other two tables. The complete database schema, along with its Relationships diagram, is shown in Figure 10.

**Nick**: It would be great if we populated the tables with data and tried to explore them a little!

**Emma**: I already have some data in Excel. I can add the third table and maybe we could then copy the Excel rows into the Access table records.

**Karolina**: This is an excellent idea. Having identically structured table in Excel we could import them into Access or simply copy in Excel and past them in Access.
Emma: Are the tables shown in Figure 11 good enough? Just in case I named them as Member, Hobby, and ActiveHobby.

Figure 10 The HobbyDB database schema in Access.

Nick: It all looks great! I can take care of the data transfer. Since your Excel workbook is already open, I will copy the table rows in Excel (Figure 11) and paste them to the Access tables.

Karolina: You guys are a great team. Now, as we have a complete database in Access (Figure 10), Nick can play with his queries. Why don’t you write your first query to show members and their hobby information for those who declared their hobbies before August 15, 2017 and have budget above $400?

Figure 11 Data for database HobbyDB in Excel.
Nick: Right away. We will need the three tables with criteria set for startDate < #08/15/2016# and annualBudget > 400. Figure 12 shows the setup in the QBE panel.

![Access Query Example](image)

Figure 12 An Access query example.

Karolina: Very good! I guess it will do. Nick, you can now add more data and start playing with the database. Remember, you can always add more entities and/or modify the existing ones in the logical model and follow up for the Forward Engineering procedures to generate SQL script. Do you have any questions?

Nick: I am good for now! Thank you Karolina and Emma for your help.

Karolina: You very welcome! It was a pleasure doing it all with you.

Emma: It was fun working with you. Thank you for this great opportunity to learn more about designing databases. Now, I can better understand how I will try to design my own database for my domain, I mean, for an Entertainment application.

FINAL REMARKS

Whether one follows a traditional software development life cycle (SDLC) or rapid development techniques (RAD), one will always run into the design phase (Gupta, et al., 2011). This phase (including its logical part) is inevitable and of an outmost importance (Smith, 2004).
Unfortunately, Microsoft Access, while being incredibly capable and rich tool, fails to fully support the logical design (Letkowski, 2015).

A question should be raised, especially in the academic context. Is it really important for business students to learn about the logical database design? Having taught this subject to different audiences (Business, Computer Science, Information Technology, Master Degree) for more than 30 years, the author strongly believes that the logical data modeling is one of the most critical knowledge components and skills one would expect from a business graduate. One of the important reasons is that business (accounting, finance, management, marketing, etc.) graduates (excluding Computer related majors) are more likely in the future to act as domain (subject-matter) rather than application development experts. Needless to say that the logical design comes very close to data modeling which has become recently one of the most demanding skills sought by businesses (Blaha, 2014). Demands for this skill are particularly fueled by the increasing popularity of business analytics (Chen, et al., 2012) and proliferation of data structures that have to a great extend successfully competed with the relational databases (Letkowski, 2017).

This paper shows how to realize a complete SDLC by complementing Microsoft Access’s apparatus with MySQL Workbench’s database design tools. A complete analysis of database topics that should be taught in business curricula is beyond this paper’s scope. However, the author strongly believes that the data modeling, in general, and logical database design, in particular, should become a solid part of the business graduates’ expertise. This can be accomplished by adopting both MySQL Workbench and Microsoft Access into the business productivity software classes. If one is convinced that the business student should focus only on critical topics, such as database design, management, and SQL queries, then MySQL Workbench along with MySQL Server (both free—kudos to Oracle), can do it all superbly.

As a follow-up of this paper, the author intends to develop a complete set of notes for teaching the vital database topics to business students, utilizing MySQL or a similar database, more fully supporting the SDLC.

REFERENCES


NEDSI 2017 Workshop Proposal

Title
Embedding real projects into the classroom to teach Internet of Things (IoTs) through agile sprint implantation methods.

Track
Information Technology & Security, Innovative Education, and/or New Prod Dev & Project Mgt

Authors/Facilitators
- Anthony P. Santella; *Innovation and Entrepreneurship Instructor; University of New England, Biddeford, ME.*
- Michael Esty; *Project/lab specialist; University of New England, Biddeford, ME.*
- Bryan E. Agosto; Sr. Project Manager/Agile Mentor, American Airlines HQ, Dallas TX
- Anna Marie Surico; Sr. Project Manager, American Airlines HQ, Dallas TX
- Chuck Stowe; PhD; Retired, former Dean Lander University, Greenwood, SC

Description
This workshop will first provide participants with basics terms and concepts of the Internet of Things (IoTs) and using agile implementations methods for an IoTs application(s). Facilitators will also share how they are creating an IoTs lab ecosystem and coaching students through pilot implementations that are using agile sprint methods and tools. Participants will hear lessons learned and some of the challenges faced by the facilitators in regards to the class project implantations, lab development, developing student support, partnerships with industry, and how to create engaging and empowering programing such as App-A-Thons and Hack-A-Thons. A portion of the workshop will be for participants to complete exercises to consider how to potentially do similar programs that leverage their school’s strengths and relationships with potential industry partnerships.

Learning Outcomes
Workshop participants can walk away able to:
- Explain the basic terms and concepts of the IoTs and agile implementations.
- Create labs and class project write ups using IoTs and agile methods.
- Identify opportunities to consider in their own schools/programs.
Expanding Cyber Security Learning in the Business Curriculum

As critical IT security challenges and threats continue to mount in society and in organizational settings of all types, the need for our students to be aware of these challenges and threats, knowledgeable about current organizational approaches to addressing challenges, and to understanding individual actions that can be taken to prevent as well as respond to IT security problems is urgent. Although MIS courses often focus on the technical side of IT security, there is often limited focus on the organizational and individual behavioral aspects of IT challenges. For example, from an organizational level, what organizational actions foster best practices for IT security? In what ways does organizational leadership and culture contribute to best practices? What kind of training and development in IT security contributes to improving team and individual IT compliance? From an individual level, what motivates an employee to be cognizant of security issues? How does an organization’s culture impact individual or team behavior with respect to security? What kind of incentives/rewards influence individuals or teams to support security policies/regulations?

These examples of some organization and individual behavior issues highlight the importance of addressing IT security issues in organizational behavior and management courses. Organizational behavior theories and concepts, related to motivation, learning, decision-making, leadership, communication, conflict, negotiation, team processes and culture, among others, are essential in understanding behavior related to IT security. In our exploration of numerous
textbooks for Management and Organizational Behavior courses, we have found few examples, cases and/or learning exercises related to cybersecurity issues. We argue that cyber security challenges are an enormous problem for business today and behavior in organizations should be introduced early in the undergraduate business curriculum so that students can become more aware of cybersecurity issues, and better understand how organizational actions and individual behavior impact security, and more fruitfully explore their behavior and knowledge related to this on-going organizational challenge.

**How Big is the Cyber Security Problem?**

Cyber security is an international epidemic today, and getting worse. Is that overstated? Juniper Research declared that "the cost of data breaches [will increase] to $2.1 trillion globally by 2019, increasing to almost four times the estimated cost of breaches in 2015" (Juniper Research, 2015). And while it is a huge concern to businesses, it is not just a business problem. Homeland Security states that "No citizen, community or country is immune to cyber risk" (Homeland Security, 2016). The current dust-up about Russian hacking into the United States presidential election process is just one dramatic and dangerous example.

So, what is the problem? Why is this problem related to management curriculum in business schools rather than, say, MIS or Computer Science classes? It is because cyber security is ultimately a business problem. For example, in business, we have technical people such as network experts to make our systems reasonably safe.
There is even a fairly mature market of security consultants who can test your business’ system for vulnerabilities and help the company become more secure. These technical resources are essential for dealing with the ongoing and ever-more-challenging technical challenge to keeping cyber secure. But, this paper is not about the technical, or “bits and bytes” part of cyber security. As it turns out, the bigger problem today is actually outside of IT: Perhaps surprisingly, over 50% of the cyber security problem is due to social engineering -- people, not machines. IBM claims "as much as 95% is due to human error" – double clicking on an infected attachment, easy-to-guess passwords, lost laptops and mobile devices, or even inadvertently supplying secure information (IBM, 2015). If true, they are stating that 95% of the 2.1 trillion dollar problem is due to people or social engineering. As a specific example of the human problem, Verizon’s 2016 Data Breach Reports that in 2016 "30% of phishing messages were opened and 12 percent of recipients went on to click the malicious attachment or link that enabled the attack to succeed" (Verizon, 2016).

Whether a cyber-attack is through computer hacking or caused by human carelessness, cyber risk and cyber incidents in businesses today are ultimately business problems, not technical problems. A cyber intrusion into a company’s customer data base is initially responded to technically – stopping the intrusion, identifying damage and cleaning up. However, very quickly, the intrusion moves into the business side of the company – legal threats, stock value, public relations as
The question this paper addresses is how we can bring cyber security to the front burner for all business students both in terms of the individual and organizational responsibility? Firewalls and cyber-attacks can be covered in an MIS class but the authors make the claim that cyber security awareness needs to be taught to all business students as a business imperative – as a management and organizational topic. Our business students need to be aware of the business problems that cyber-attacks can cause and some understanding of how to participate in an organizational effort to prevent cyber-attacks as well as effectively respond if there is a cyber incident. The next section presents an assignment that is self-contained, engaging, light on technology and effective in presenting the broad, organizational impact of a cyber-attack.

The Assignment

The Cyber Security Awareness assignment is anchored in a Harvard Business School Case – iPremier (A): Denial of Service Attack. As stated in the abstract, the case:

*Describes an IT security crisis, and raises issues of risk management, preparation for crisis, management of crises, computer security, and public disclosure of security risks* (iPremier, 2009).

This case takes the student through an actual cyber-attack, one called a DDOS or Distributed Denial of Service Attack. The entire case covers about 45 minutes of
time. iPremier is a fictitious, small e-commerce company whose web site has gone down. For an online company, this is equivalent to shutting the doors to the company. The case ends right after the cyber-attack ends.

The main point of the case is to illustrate how quickly this cyber-attack moved from a technical issue to an organizational issue. The impact of the attack quickly involves individuals at all levels of the organization and highlights the challenges of individual and group problem-solving processes. The case reveals the importance of organizational procedures and their implementation, concerns of how culture impacts organization actions, and the necessity of having clear communication protocols to address crisis situations in organizations. Involvement by the CEO and Corporate Counsel spotlight the critical role of leaders and leadership behaviors. Ultimately, business problems become the focus: will iPremier survive; what are the impacts of shutting down the company for a few days on the company brand or the company stock price; what does it mean to have the FBI involved; what are the ethical standards to be applied to notifying customers?

Overview

The Cyber Security Awareness assignment is in two parts. First there is an individual case write-up worth 10% of their semester grade. Second, there is a class that spends 20 to 30 minutes discussing the individual case write-up along with an hour-long class discussion and role-play where iPremier (the class) is presented with additional cyber-attack related problems that they solve during the class.
Part I – The Individual Assignment

The first part of the assignment, an individual assignment, is to analyze the case and make recommendations about what the company should do next, after the cyber-attack stops. The written assignment is due the day the case is discussed. As preparation for the assignment, students are provided a very quick explanation of DDOS attacks, supported by a diagram in the case, and a description of the requirements for the case write-up. The authors use the case as an opportunity to practice brief, concise business writing by requiring the case write-up be limited to one page. Appendix A shows the template provided.

Part II – A Class Discussion and Role-Play (90 minute class)

The first 15 minutes of the class focuses on the student’s Problem Statements. Students meet in groups of 3 and share their case write-ups with each other. They are encouraged to talk about their Problem Statements and challenges associated with the written assignment.

The next 15 minutes is a general, instructor led discussion of the best alternatives and recommendations students’ identified. This discussion typically results in a fairly clear consensus of what the company should do next.

The last 60 minutes of the class are about the students taking the case forward in time, beginning two weeks after the cyber-attack. This is done through students
role-playing as key people in the iPremier organization. Students are asked to volunteer to play the part of the various people, from the CEO to a special cameo appearance by the FBI. Appendix B lists the characters involved. The students who are role-playing are asked to the front of the room. The faculty member explains that iPremier will now encounter several new problems and introduces problems (at different times) during the next 30 minutes. The goal of the role-playing group will be to work, as an executive committee, through these problems in front of the class. All discussions are public so the rest of the class can listen to how each problem is solved. The CEO makes the final decision about what actions will be taken for each problem presented. Students not role playing are available to the CEO to call on, as expert consultants, so students in the audience can still participate.

The instructor then walks the iPremier executive committee through 4 problems identified in 2, short follow-up cases (iPremier (B), 2009 and iPremier (C), 2009). The students do not get copies of these 2 short cases. The instructor distills the 2 cases into a sequence of live problems that have to be solved in class. The four problems are:

1. With inconclusive evidence whether the cyber-attacker just disabled the company website (never penetrated the company firewall) or actually penetrated to customer files, should iPremier shut down for a few days and do a complete rebuild? The other alternative is to keep their doors open and, since there is no concrete evidence that the hack got through the company
firewall, assume the hack did not penetrate the firewall and expose customer data.

2. Assuming that iPremier did NOT do the rebuild, what happens if the FBI shows up and says that iPremier has been, unknown to iPremier, conducting a cyber-attack on its number-one competitor MarketTop? Do you then do a complete rebuild of your computer systems and shut down for a few days?

3. How does iPremier handle the situation with MarketTop?

4. While, at this point since the firewall has been penetrated, it is clear that customer data containing credit card information could have been stolen but there is no actual evidence it was. Should iPremier disclose publicly what happened – that is, that customer data might have been affected? What should they say?

The discussion of each of the 4 problems is facilitated through the interjection of quotes by different iPremier people. A sample of these quotes, shown in Appendix C, are provided to the right “person” at the right time to provide needed context and information to help move the discussion along.

The above questions open up a lot of room for discussion. A suggested, additional list of questions for the instructor to bring up are listed in the table below, grouped by topic.
Table 1: Curriculum Topics Covered in iPremier

<table>
<thead>
<tr>
<th>More General Question</th>
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<tbody>
<tr>
<td><strong>NOTE:</strong> A Full Cyber Security Response Plan for a company includes education, planning and incident response.</td>
</tr>
</tbody>
</table>

**Decision Making**

- Who should make this/these decisions?
- Who will be responsible for communicating and implementing the decision?
- What impact will your decision have on organizational practices?
- What impact might your decision have on individual employees or teams in the organization?
- How will this decision impact employee motivation?
- What impact might the cyber-security attack have on organizational culture?

**Conflict Resolution**

- How does iPremier think about responding to the startling information that they are cyber-attacking their #1 competitor? Who should be at the first meeting between iPremier and MarketTop?

**Ethics and Your Company's Customers**

- What is your company's ethical standards for letting their customers know about possible and/or actual cyber-hacks into customer information such as credit card information? While a number of states have laws now requiring disclosure, for this discussion, it is best to let iPremier have the option to not disclose, then hear the discussion and the decision.

**The Business Value of Cyber-Security**

- Perfect security is not possible. However a bank has a greater need for cyber-security than a mom-and-pop book store. How should the business value of cyber-security be established? For example, what does it mean financially and for the brand for an e-commerce company like iPremier to be shut down for several days?

**Education & Training**

- In the case, it was clear that the technical people did not have updated documentation and had not practiced incident response with Qdata. Likewise, management was working this out "on the fly". What is involved in developing...
and implementing the kind of regular education & training needed here? If there is a Board of Directors, should they be involved? Are they legally responsible? Briefly introduce the growing use of cyber-insurance by companies (Floresca, 2014).

Involving Law Enforcement Organizations (LEO’s)?

What is the organization’s stand on involving LEO’s? For ransomware, as an example, half the organizations handle the situation without involving LEO’s.

What have we learned?

Re-emphasize that cyber-security is rapidly becoming a multi-trillion dollar problem globally every year. And while the network/computer side of the problem is obviously important, the ultimate responsibility is with the functional or business side. They have to establish the importance of their business systems and business data in order to set the appropriate level of security and its accompanying cost. Information and information systems are an asset of the company and the individual manager and needs to be managed – working in conjunction with the IT experts.

Conclusion

We all know there is a cyber security problem. Most of our business students don’t know how deep and wide the problem is. All of our business students in 2017 need to know about the enormous threat that cyber security is to all of us both as individuals and to the companies where we work. The assignment presented in this paper provides an effective way to begin to create deep awareness of the depth and impact of cyber-attacks on an organization.

The authors have used this assignment in both core MIS classes at the MBA level and in undergraduate OB classes. While the MIS class discussion includes a little more discussion of the technology, the predominant focus quickly moves to the non-technical, business issues in both MIS and OB classes. The fact that iPremier is a
small company helps students get their arms around the different parts of the
compagny represented here by individuals. The quotes provided give the students
both perspective from different areas in the company and also facts they must deal
with.

At the end of the semester in their student evaluations, the iPremier assignment is
always one of the most frequently mentioned highlights of the class. The
assignment works because it tells an interesting story and also engages students, in
class, with several challenges – challenges that touch on broad, deep topics but with
specific problems that can be worked through in a group, in class, facilitated by an
instructor.

**Addendum – Cyber-Security Resources**

The topic of cyber security covers a wide variety of topics, most basically labeled
“bits & bytes” or the technical side and the “human firewall” or the human side. The
assignment can be used with a minimum of technology background – a brief
description of DDOS, which is supplied by the case -- since the focus is on
understanding the organizational response or lack of response. However, for those
instructors who would like to learn more about the topic or would like to provide
their students succinct resources by way of an introduction to cyber-security, this
paper provides some in Appendix D.
References


APPENDIX A
Template for Case Write-up Memo

MEMORANDUM
To: Prof. Timothy Shea
From: John Smith (insert your name)
Date: January 28, 20xXX (insert date that you turn in the assignment)
Subject: Case Summary: XXX Case

Problem Statement (do this first)
Problem Statement that identifies the problem(s) at hand, as you see it. Limit the problem statement to 1 or 2 sentences. The Situation section and the Alternatives section both need to relate to the Problem Statement.

Situation
Summarize the general situation and background – Not everything, just those items related to your problem statement.

Alternatives
This section is typically a statement of options, combined with a brief assessment of those options. You may use “bulleted” paragraphs to present chunks of information or ideas. When possible, include quick pros and cons with each option.

Recommendation(s) and Next Steps
Chose and quickly defend the alternative(s) you have chosen, based on the alternatives above. This is a chance to both recommend a solution and elaborate on the merits of the alternatives you picked. The final couple of sentences should indicate, broadly, what the next steps should be in order to implement the alternatives.
## APPENDIX B:
The iPremier Parts for Students to Role-Play

<table>
<thead>
<tr>
<th>Name</th>
<th>Title</th>
</tr>
</thead>
<tbody>
<tr>
<td>Peter Stewart</td>
<td>Lawyer</td>
</tr>
<tr>
<td>Joanne Ripley</td>
<td>Operations</td>
</tr>
<tr>
<td>Tim</td>
<td>Operations</td>
</tr>
<tr>
<td>Leon Ledbetter</td>
<td>Software Stud</td>
</tr>
<tr>
<td>Warren Spangler</td>
<td>VP Business Development</td>
</tr>
<tr>
<td>Bob Turley</td>
<td>CIO</td>
</tr>
<tr>
<td>Jack Samuelson</td>
<td>CEO</td>
</tr>
<tr>
<td>Lydia Dawson</td>
<td>Marketing</td>
</tr>
</tbody>
</table>

**Cameos**

- Hotel Maid
- Donald Reedy FBI agent
APPENDIX C

Sample Quotes to Facilitate Role Playing

iPremier (B)

Quotes to support problem #1 – Does iPremier do a complete rebuild of their computer systems?

Joanne Ripley – Operations

"I recommend that we disconnect all production computers from the Internet and rebuild the software systems on all of them from scratch. The operations staff estimates that the company would need to completely shut down for 24 to 36 hours to complete such a comprehensive rebuild. Although the rebuild process is theoretically well documented, I should caution everybody that there are some people in operations that are concerned that there might be hiccups during the rebuilds that could delay getting everything back on-line. That is, it might take more than 36 hours.

Warren Spangler – VP of Business Development

"It would be irresponsible of us to take such an action knowing that it was certain to significantly degrade customer satisfaction at a time when we are trying to maintain sales and profit growth in the face of fierce competition."

"Besides, iPremier's situation is pretty much the same as it had been before the attack. There is no evidence that production equipment has been compromised"

iPremier (C)

Quotes to support problem #1 – What do you do when the FBI shows up with some news?

FBI Special Agent Donald Reedy, talking with the CIO Bob Turley

"I am here to inform you that for the past two hours, iPremier Company's biggest competitor, MarketTop, had been experiencing a denial of service attack."

"The source of the attack was from inside iPremier's production computing installation"
APPENDIX D

Cyber-Security Online Resources

Creating a Culture of Awareness, https://staysafeonline.org/re-cyber/
The best security technology in the world cannot help you unless employees and CEO understand their roles and responsibilities in safeguarding sensitive data and protecting company resources. This will involve putting practices and policies in place that promote security and training employees to be able to identify and avoid risks.

Video -- Stop Think Connect https://www.youtube.com/watch?v=47vtDPcU14o

Tip Sheets
- Stay Safe Online -- www.staysafeonline.org
  - Technology Checklist for Businesses
  - Protect Your Customers
  - 5 Ways to Help Employees Be PrivacyAware
  - Privacy is Good for Business
  - Stay #CyberAware While On the Go: Safety Tips for Mobile Devices
  - Safety & Security Tips On the Go Brochure
  - Victims of Cybercrime
  - Data Privacy Day, January 28th
  - Glossary of Terms
  - Cyber Security 101
  - Ransomware Facts & Tips
  - Privacy Tips for Using Public Computers & Wireless Networks
  - Tips for Passwords & Securing Your Accounts
  - National Cyber Security Awareness Month (October)
- Presentation for Undergraduates http://www.stcguide.com/explore/student/

Sample Infographics
- Stay Safe Online – www.staysafeonline.org
  - Navigating Your Continuously Connected Life
  - Tech support scams and how to avoid them
  - Fight Against Fraud: Recognizing and Combating Cybercrime
  - Creating a Culture of Cybersecurity From the Break Room to the Boardroom
  - STOP. THINK. CONNECT. Infographic: History and Milestones
  - TRUSTe/National Cyber Security Alliance U.S. Consumer Privacy Index 2016 Infographic
  - Cyber Career Paths Infographic
  - Creating a Culture of Cybersecurity in Your Business Infographic
  - Creating a Culture of Cybersecurity in Your Business Infographic
  - 3 Reasons Hackers Love Your Small Business Infographics
Exploring Social Media's Impact Effect on Preventing Groupthink

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Introduction

The impact social media technology has on society presents interesting challenges and research areas for social scientists across disciplines beyond information technology, including psychology and sociology. As the adoption of social media becomes more commonplace in society, its influence cannot be understated. Since its inception around 2005, social media usage continues to grow at a phenomenal rate accounting for 22% of time spent online in the United States as of June 2010 (Nielsen, 2010) and this influence spans generational divides as well as cultural divides (Kaplan and Haenlein, 2010). This increasing influence emphasizes the importance of understanding the effect of technology on behaviors, both at an individual and group level. Exploring psychological phenomena such as cyber stalking and cyber bullying, as an example, have increased over the past few years (Campbell, 2005; Li, 2007; Hindujab and Patchin, 2008) as media attention focuses on high profile events. Further, Information Technology researchers have explored the nature of technology on groups such as group decision-making efficiency and quality (Kline and McGrath, 1999). Due to the novelty of social media and its inherent group characteristics, it would seem that researching psychological behaviors due to social media, especially those related to small groups, would be a logical step.
Social media technology allows users to communicate both asynchronously and synchronously, depending on the specific characteristics of the artifact used. Facebook, for example, allows users to communicate bi-directionally through wall posting, direct messages or via instant messaging, while Twitter allows communication through a primarily one-way asynchronous model. However, what effects do interpersonal communication and the reach of the network have on social media and its participants?

As group dynamics morph in this new online environment, examining the nature of its effects on classical psychological theories could prove valuable. Psychologists since the early 1970's have examined the effects of media and groups in decision making, with the first study of computer assisted decision making occurring in 1982 (Fjermestad and Hiltz, 1997; Truoff and Hiltz, 1982). Psychologist Irving Janis (1972) proposed this theory to explain resulting bad decisions, called 'fiascos'. The groupthink debate continues to illicit research both affirming and disproving its validity 40 years later.

Exploring groupthink in a social media setting could help future researchers in understanding its’ possible effects of groupthink. More importantly, by exploring distinctions between group decision support systems (GDSS), researchers could utilize the differing concepts between systems specifically designed to support group decisions, and systems designed for social interaction that are used for group decisions. This paper proposes an experimental procedure to determine the validity of certain antecedents of groupthink using social media.

**Groupthink**
Group decision-making presents challenges in terms of processes and outcomes. The process of decision-making, covered extensively in organizational theory literature represents the core of "the Carnegie School" line of thought (Simon, 1957; Tolbert and Hall, 2009). According to this line of thinking, individuals were characterized by bounded rationality (Simon, 1957), which limited an individual’s capability for evaluating every alternative. Bounded rationality also stated that even limited, individual's cognitive capabilities were good enough such that outcomes could be considered adequate (Hogarth, 1981). Cognitive biases and heuristics have been extensively researched in strategic decision making literature. Based on bounded rationality, heuristics should be somewhat useful since they provide individuals with 'rules of thumb' and 'short cuts' for decisions; however, while they have been shown to be useful in experimental studies, they also can lead to significant errors and problems (Schwenk, 1988).

The aforementioned biases play an important role since it is not possible to consider every alternative for every outcome. Biases including the availability bias, i.e. information readily recalled increases the probability of certain judgments, may prove effective for quick decisions but might yield ineffective ones (Schwenk, 1988; Hogart, 1981). The presence of these individual biases may have a compounding effect on other individuals within a group required for a collective decision, and thus individuals can view problems from different perspectives and have different preferences on outcomes (Mohammed and Ringseis, 2001). The type of decision undertaken by individuals however affects the amount of bias that might be present in the decision.
Although individuals within a group may share a common goal, the decision making process can differ based on the perceptions of causes and preferences to outcomes. Thompson (1967) describes these two major dimensions regarding the decision making process as first, the causes, and second, the outcomes of decisions in terms of certainty and uncertainty.

<table>
<thead>
<tr>
<th>Causes &amp; Effects</th>
<th>Outcome Certainty</th>
<th>Outcome Uncertainty</th>
</tr>
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<tbody>
<tr>
<td>Certainty</td>
<td>Computational</td>
<td>Compromising</td>
</tr>
<tr>
<td>Causes &amp; Effects</td>
<td>Judgmental</td>
<td>Inspirational</td>
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<tr>
<td>Uncertainty</td>
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*Table 1: Thompsons' Dimensions of Decision Making*

He argues that there are four major decision making processes based on these two dimensions. First, when the causes are certain and the preferences regarding outcomes are certain, the decision-making process will be *computational*. Second, when the corresponding dimensions are both uncertain, the decision making process will be *inspirational*. The other two possibilities are characterized as *judgmental*, when outcome preference is certain but cause is uncertain, and *compromising*, when outcome preference is uncertain, but cause is certain. These differing processes will almost certainly yield different results based on the perceptions. Group members differing assumptions and interpretations may impact the ability of each individual to view the problem or task in a similar fashion and thus the process chosen must work to reconcile the differences addressing the varying assumptions and perspectives (Mohammed and Ringseis, 2001).
In both cases uncertainty in one dimension are interpreted and analyzed based on individual preferences, and thus individual factors such as social influence, intuition, negotiation, openness can impact the decision making process and thus the quality of the decisions (Miesing and Wolfe, 1985).

Janis (1972) presented his theory on groupthink, in an effort to explain the conditions under which faulty decisions are made within group environments. It is described as extreme concurrence sought by decision-making groups (Janis, 1972; 1982; 1989; Turner et al., 1992). In this theory, he describes particular antecedents of groupthink, which lead to symptoms of group groupthink, manifested as symptoms of faulty decision-making and thus the likelihood of an unsuccessful outcome (Park, 1990). It is important to note that the antecedents of groupthink were grouped into three categories of group cohesion, structural faults and situational contexts (Park, 1990). The antecedents and symptoms of groupthink have been the target of much debate including proposals of minor and full revisions of the theory, to complete dismissal (Turner and Pratkanis, 1998).

Groupthink's antecedents have been a primary focus of much of the work conducted to test the validity of the theory (Park, 1990). Since its inception in 1972, until 1990, only 16 empirical studies were performed, and in many cases, due to the complexity of testing all the antecedents simultaneously, only two were tested simultaneously in any one paper (Park, 1990).

Janis grouped the antecedents, a primary focus of researchers, into three categories. Group cohesion, Janis believed, was a necessary, but not sufficient, antecedent for groupthink (McCauley, 1998). This concept has been argued by many
researchers, since the evidence of high cohesion as necessary is inconclusive (Turner and Pratkanis, 1998). Cohesion, rewards of remaining in a positive group atmosphere or condition (Janis, 1972), may be difficult to replicate in a laboratory environment due to the inability to replicate the necessary conditions for rewards and desire of the group status. Researchers have attempted to operationalize through friendship (Flowers, 1977), prior classroom work (Leana, 1985), and personality compatibility (Callaway & Esser, 1984; Callaway et al., 1985). While other studies have shown that high levels of cohesion among group members could have an adverse impact on group interactions (Zacarro and Lowe, 1988), some studies have shown that higher levels of cohesion may reduce conflict and increase collaboration (Moorehead and Montanari, 1986), and that cohesion among groups may be more productive and simultaneously produce better quality decisions (Keller, 1986).

The structure and processes of the group form the next set of antecedents for groupthink, insulation of the group, leadership style, lack of norms and methodological procedures, and social homogeneity (Janis, 1972). The other antecedents, forming the situational context set include, high stress, recent failures difficulty of the decision-making task and moral dilemmas. Only group cohesiveness, group insulation, leadership style, and methodical procedure were empirically studied in any detail (Park, 1990), thus the research, while extensively reviewed, is empirically limited due to the complexity and the limited ability to create measured adequately matching the original theory.

With the high level of debate and discontent with groupthink, it continues to pique the interests of researchers. Researchers have examined groupthink and incorporated it in disciplines such as political science, social psychology and organizational behavior
(Turner et al., 1992). In spite of the lack of conclusive findings on the antecedents or symptoms, some researchers argue that this isn't necessarily a fault of the theory. Researchers in information systems, more specifically group decision support systems (GDSS), began to focus their efforts on these antecedents and symptoms and test groupthink from an entirely novel perspective.

Group Decision Support Systems (GDSS)
The study of the use of technology on decision-making dates back to the mid 1970's; however, the first clear research of GDSS begin in 1982 with Turoff and Hiltz (Fjermstad and Hiltz, 1988). Decision theorists have viewed technological advances as a means to overcome weaknesses inherent in human decision-making (Rice, 1984). It was generally believed that the deployment of technology should increase the effectiveness, and productivity of decisions, since decision-making would be more objective (Desanctis and Poole, 1994). Group Decision Support Systems (GDSS) were designed to meet the challenges of decision-making and thus improve the effectiveness.

In 1985, University of Minnesota created a program to study the effects of GDSS in a controlled environment and over the years would examine nature and composition of the group, the tasks being conducted, and various changes to the technology interface (DeSanctis et al. 2008). The technology that comprises a GDSS generally combines communication mechanisms and decision support capabilities for problem solving (Descantis and Poole, 1994). The technology can support a wide variety of group formations and structures including face to face and distributed meetings in real-time or longer periods, therefore more asynchronous time period (Descantis and Gallupe, 1987).
GDSS require more than communication technology, they must support decision modeling, which may require processing, analysis and data storage and retrieval (Er and Ng, 1995).

As decision theorists sought to explore how GDSS can be effective in decision-making a number of issues emerged. First, some studies reported conflicting results between GDSS groups and non-GDSS groups on group consensus and decision quality (George et al. 1990). Furthermore, identical technologies appear to have been used in different manners across groups (Hiltz and Johnson 1990, Kerr and Hiltz, 1982). Technology properties have been shown to play a significant role in the outcomes of decisions (Descantis and Poole, 1994). The problem is further compounded by the inability to replicate reported effects consistently across studies (Jarvenpaa et al. 1988).

Over the years, two prominent theories emerged to explain the variances in GDSS. First, it was proposed that effective use of technology was contingent upon proper appropriation of the technology for a given task. This appropriation became known as Task-Technology Fit (Zigurs and Buckland, 1998). Second, by combining concepts from the decision-making school and institutional theory, it was posited that the effective use of technology was predicated on the structure of the technology that could properly model the interplay between technology, social structure and interaction (Descantis and Poole, 1994).

Assuming that GDSS improves performance in generating higher quality decisions more effectively, it can be inferred therefore that GDSS must reduce the likelihood of groupthink, characterized by ineffective decision-making. Miranda (1994) proposed that GDSS could be used to avoid groupthink in situations due to the increased
level of anonymity, immediate input and feedback, various process structures, common interfaces, e.g. public screen, and increased access to external information. By provisioning for structure and process (DeSantis and Poole, 1994; Zigurs and Buckland, 1998), GDSS should mitigate the antecedents as predicted by Janis (1972); furthermore, GDSS can facilitate anonymity increasing the level of feedback and reducing the fear of censure or retribution (Miranda, 1994).

Recall that, arguably, one of the necessary conditions for groupthink, according to Janis, was presence of group cohesion. GDSS technology appears to have a significant positive relationship with group cohesion (Chidambaram, et al. 1990), which demonstrates a significant positive relationship with decision quality (Mennecke & Valachich, 1998) and more specifically in disjunctive and conjunctive tasks but not additive tasks (Lam, 1997); however, additional research has shown that correlation of group cohesion with decision quality, confidence and satisfaction as perceived variables from an individual perspective were found significant, but the effectiveness, measured in decreased time was not found significantly correlated to group cohesion (Schwarz and Schwarz, 2007).

Over the years GDSS technology has evolved, but simultaneously, the industry has experienced the emergence of social networking sites such as Facebook and Twitter, where users utilize the IS artifact for a number of activities (Lenhart, 2009). Information sharing, communication and collaboration continue to evolve in social computing and online communities (Zeng et al. 2007) and therefore it is important to examine how these types of technologies might affect decision-making.
Social Media

Social Media technologies have gained widespread popularity. Facebook, Twitter, and YouTube are all examples of sites and technologies that enable users to generate content, connect with others, and even collaborate. Facebook alone boasts about 1.7 billion active users, with each user being connected to 300 other 'friends', and the average user connected to 80 community pages, groups and events (Facebook, 2011). The Like and Share buttons on Facebook are used on an average on 10 million webpages everyday. With a large user base and highly connected groups, it would seem likely that these technologies could be used to effect decision making on a number of topics, and in fact these technologies are used to organize groups, gather intelligence (Burns and Eltham, 2009), increase political influence (Shirky, 2011), attract members to issues (Facebook, 2011), market to consumers (Thackeray et al. 2009) and collaborate on projects, such as Facebook Causes, an app designed to bring people together for a common task or charitable task.

Since social media has encompassed a large number of technologies and has been broadly defined by these technologies, a classification needs to be drawn to help target more effectively the characteristics and attributes of the technology that might be used for decision-making. The two defining dimensions for the classification rely on the media artifact, and the social process engaged (Kaplan and Haenlein, 2010). Specifically, the authors note that sites such as Facebook, ranked high in self presentation / disclosure, elements of the social process, and due to a higher prevalence of social presence, i.e. intimacy and immediacy, and media richness, a more robust artifact. Therefore, the
existing literature on GDSS could be leveraged for an understanding of group decisions using social media.

Anonymity has been reported as a significant advantage to higher decision quality when using GDSS because it offers an environment free from threats thereby reducing inhibitions resulting in more contributions, an environment of equal participation and a removal of social barriers (Pinsonneault and Heppel, 1997). However, the results of GDSS on anonymity have been mixed, possibly as a result of the context, type of decisions and nature of the tasks (Er and Ng, 1995). Furthermore, while anonymity has been reported as reducing social barriers by eliminating static cues in Computer Mediated Communication (CMC), the same effect has also been reported to an increase in irresponsible behavior (Sproull and Keisler, 1986).

While studies have shown that the combination of GDSS with Face to Face meetings are more apt to reach consensus (Er and Ng, 1995), Level 1 GDSS without face to face appear to be perform better than face to face in certain types of tasks such as more open ended and higher complexity tasks (DeSantis et al. 1998), similar to Thompson's tasks categories, judgmental and compromising. Thus anonymity might be a factor when there is more ambiguity in the information and less is known about the potential results, such that participants may be more apt to contribute when the degree of uncertainty is high and their responses can be more anonymous. Anonymity increases the perceived distance between participants, and thus could negatively impact decisions and tasks having a social component and, by itself may be too complex and unpredictable because of situational factors and ultimately as a single construct may not be sufficient (Pinsonneault and Heppel, 1997).
Social media, as a Level 1 GDSS, while similar to email, chat forums and simple text messages, does however present a different angle. If social media increases the social presence over email and chat forums as suggested by Kaplan and Haenlein (2009), then proximity issues may not be problematic; however, depending on the level of perceived anonymity, lower quality decisions might be prevalent when dealing with a socio-emotional decision and more judgmental task such as a jury decision, i.e. a task with cause and effect uncertainty but outcome certainty.

Therefore, it is possible that social media, in a manner similar to GDSS, might create an environment that is highly cohesive, and that under a simultaneously present set of antecedents and factors, the group might be susceptible to groupthink; however, because of the level of control in participation and anonymity, social media might counteract the situational and process factors, and thus decisions made within a social media environment might not be more prone to groupthink.

**Research Questions**

As discussed in the literature review, there exists a natural curiosity of exploring how technology, specifically, GDSS technology, might prevent groupthink. Although very difficult to model and replicate, groupthink scenarios have been tested using GDSS, by examining decision quality, number of outcomes based on anonymity (Jessup et al, 1990), and cohesion (Chidambaram et al, 1990). The contribution of this paper is to explore the effect of groupthink antecedents, anonymity and cohesion with social media. More specifically, this paper explores a specific type of task that is more open-ended with
a more judgmental decision making processes as prescribed by Thompon (1967). Using a sample court case and mock jury deliberation, it is believed that certain elements of a judicial process can create an environment that will allow for the effective manipulation of anonymity and cohesion. The deliberation of juries is a well-known construct that requires, in at least criminal cases, unanimity for conviction. It possesses external threats and time pressures and exhibits a degree of social influence, i.e. the decision has societal implications. These deliberations are clearly bounded by information provided during the case, have external pressures to yield a verdict suitable to society, require deliberations between peers who may or may not have expert opinions regarding the case, but are required to render a decision (Mitchell and Eckstein, 2009). Pressures for juries can be very influential (MacCoun, 1989), thus leading researchers to believe that juries can fall victim to groupthink, but that it is not necessarily inevitable (Mitchell and Eckstein, 2009).

The literature review revealed no published articles that utilize a GDSS or social media artifact for the specific purpose of exploring groupthink in a judgmental setting, although the use of GDSS for jury deliberations has been discussed for deliberations (Field et al., 1996). In the paper, the authors examined and reported the results of a single day pilot study in Fairfax, Virginia. The authors believed that more research was warranted, however the pilot study employed the use of a GSS Facilitator who was not part of the jury. This facilitator may have been necessary to ensure proper use of the GSS tool, a point raised by Dennis et al. (2001) about the importance of appropriation support in the presence of task technology fit.
By attempting to create a laboratory experiment of a jury deliberation, it is possible to examine the possible effects of manipulating factors such as anonymity and cohesion. Since artifacts like social media can allow users to control the amount of information provided to the group, this paper will focus on manipulating anonymity and studying the effects on decision quality and simultaneously attempt to determine participants level of perceived cohesion. Thus, the key focus of this paper is to explore the effect of anonymity and cohesion together using a social media setting under a judgmental, high pressure and socio emotional task. The experiment attempts to further fulfill Janis’ requirement of cohesion as a necessary but not sufficient condition for groupthink in a highly structured environment.

Figure 1: Proposed Hypothesis
Specifically, the paper will explore the direct relationship of anonymity on generating alternatives, decision quality, effectiveness of decision-making and the level of perceived cohesion.

$H1a$: Groups using social media with full anonymity will have a greater number of alternatives than groups without full anonymity.

$H1b$: Groups using social media with full anonymity will reach decisions faster and thus be more effective in decision-making.

$H1c$: Groups using social media with full anonymity will have a higher decision quality than groups without full anonymity.

$H1d$: Groups using social media with full anonymity will have a lower level of perceived cohesion.

In addition, the paper will control for perceived cohesion, and explore its moderating effects on the dependent variables of decision alternatives, decision quality and decision effectiveness.

$H2a$: Higher levels of perceived cohesion will negatively moderate the relationship between anonymity and number of decision alternatives.

$H2b$: Higher levels of perceived cohesion will negatively moderate the relationship between anonymity and decision quality.

$H2c$: Higher levels of perceived cohesion will negatively moderate the relationship between anonymity and decision effectiveness.
METHODOLOGY

As described in the literature review, many researchers have found it difficult to provide an experiment that can test the groupthink theory effectively, and have cited many causes for this. It is believed that by creating a well-known judgment oriented task and creating pressures that can be effectively simulated in the laboratory, that the environment might be conducive to groupthink phenomena.

Environment

The proposed environment will create a scenario that should meet Janis’ criteria for structural faults. Subjects who participate will be informed that they are a part of a NY State government pilot study to explore the use of social media in jury deliberations. This condition should create a degree of legitimacy and provide for a pressured and high stress environment. Second, jury deliberations are fraught with uncertainty and in some cases represent significant moral dilemmas, especially when confronted with situations requiring a criminal conviction. Third, jury participants are selected from the general population without necessarily having any knowledge of the specifics of the case or of the subject matter presented. Thus, the decision making process is overall more difficult without any particular knowledge of the subject. Further, this makes the participant pool of students especially valid and increases the internal validity of the study.

Another set of antecedents met by this experiment center on the structural faults. Since jury deliberations have no formal structure, except for the appointment of a jury foreman, no structure or set of process generally exists. All participants are considered
equal and the method they choose to determine guilt or innocence is entirely up to the group. Further, the sequestering of juries makes it impossible to use any other information from outside the group, another critical requirement for groupthink.

Thus, the jury setting might present one of the most suitable environments for testing groupthink and decision-making. The overall judicial process is widely known and as such makes it easier for subjects to understand. By incorporating a new IT artifact, it is possible to control for potential confounds and hopefully provide more insight into the effect of social media on anonymity and cohesion. Further by removing the GDSS facilitator, implemented in the Virginia pilot, the group will more closely resemble a practical setting.

**Manipulations**

The primary manipulation will be the level of anonymity for the participants in the group. Ensuring that they cannot see each other, by placing them in separate rooms or cubicles will help facilitate the anonymity. In one case the experiment will allow the users to use their Facebook profiles or alternative demographic information. In the other case no personal or demographic information will be provided and each person will be identified in the artifact as "Juror 1", "Juror 2", etc. Information regarding the perceived level of cohesion will be accounted for by utilizing the PCS scale.

**Limitations**
While the proposed experiment has promise, it is not without its limitations. First and foremost, as every experiment conducted in this area has faced, groupthink itself poses the most serious challenge. It is clear that this experiment doesn't attempt to manipulate all the conditions for groupthink, but does make every attempt to control for key ones to see if the conditions might be right for groupthink.

Secondly, as an Information Systems paper, the notion of the IT artifact must clearly be present and not be taken for granted (Orlikowski and Iacono, 2001). Even though this paper references social media as a level 1 GDSS and uses the artifact as a clearly understood tool for participants, i.e. Facebook is widely used and understood, and further represents the intent of the exploration of this paper, i.e. the impact of social media on psychological theories, one could question whether this experiment fits the criteria. However, considering this particular IT artifact as a tool for social relations (Orlikowski and Iacono, 2001), it is hoped that this particular usage of the IT artifact may be beneficial in adding to theory around the impact of technology toward decision making and sociological issues.

Next, the validity of the court case and environmental context could be questioned. While every attempt will be made to ensure a realistic context, it will still be understood that the experiment is a pilot and not an actual court case, thus inhibiting the pressure and stress antecedent required by Janis. In addition, the practicality of the experiment could be questioned, since all the students come from the same university and there is an increased likelihood that demographic knowledge will be transferred either prior or during the experiment, i.e. participants might know who is participating, even though they might not exactly know the exact identity of the individuals.
Further questions might arise around whether or not anonymity is effectively present in this experiment. It might be argued that disinhibition, of which anonymity is one antecedent of many, is really the characteristic that should be explored and is responsible for the behavior of individuals (Pinsonneault and Hippel, 1997). Thus, future studies might seek to explore the levels of disinhibition in a social media context.

**Results & Conclusion**

The purpose of this paper is to begin an exploration of the effect of social media on various psychological theories. Social media technologies like Facebook are high in levels of self-presentation and disclosure and richer in media attributes (Kaplan and Haenlein, 2010). They lack attributes of previously studied complex GDSS, which provide for modeling and decision support facilities, but can be accurately described as tools similar to level 1 GDSS. The very nature of these technologies are designed to support group interactions and the virtual socialization and makes them very interesting areas of research. By focusing on traditional theoretical concepts such as groupthink and attempting to create experiments that can expose the psychological and sociological impact of social media, it is hoped that a better understanding of the effect these tools have on individuals and society can be achieved.
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APPENDIX A: Example Facebook Application

[Image of a Facebook application interface]

Appendix B: PCS Sample Questions

Perceived Cohesion Items

Items listed as "B" are for the Belonging Factor, and those listed as "M" are for the factor Morale.

1. I feel that I belong to this group. (B-1)
2. I am happy to be part of this group. (M-1)
3. I see myself as part of this group. (B-2)
4. This group is one of the best anywhere. (M-2)
5. I feel that I am a member of this group. (B-3)
6. I am content to be part of this group. (M-3)

NOTE: Originally, Bollen and Hoyer (1990) used a 10 Point Likert scale; however, Chen et al., 1999) used a 7 point Likert scale, which is what will be used in this case. (strongly disagree, quite, slightly, neither, slightly, quite, strongly agree)
One of the key skills that typical business school students must have when graduating is proficiency in Microsoft Excel. Historically, students in the Lynchburg College School of Business and Economics would learn Microsoft Excel informally through their college career and then formally through one or two projects in the upper-level MIS course. One problem we diagnosed was that students would enter the MIS course with insufficient training in Excel. The projects would greatly benefit from a greater prerequisite training than students typically possessed.

Therefore, our goal was to increase exposure to Excel early in business students’ studies. We did this by implementing a series of Excel assignments in select sections of Principles of Microeconomics and Principles of Macroeconomics. In each course, students completed seven mini-Excel projects. Initial assignments contained detailed instructions, while later assignments required the students to build on what they learned and think for themselves on how to achieve a task.

Over the past year, most of these students completed the upper-level Management Information Systems course required of all business majors at Lynchburg College. The first assignment in this course is an Excel project. Because not all students took the Excel-intensive economics courses, we can assess the impact, if any, of the early Excel exposure. Comparing performance on the project between those who took the Excel-intensive economics courses and those who did not, we found no statistically significant differences between the two groups.

We are now in the process of assessing why it appears that early Excel training in economics principles course has no effect on performance on upper-level Excel proficiency.
Investigating the Adoption of Public Cloud Computing Services

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ABSTRACT

Cloud computing utilizes the Internet to provide businesses with high levels of computing power without the need to establish their own datacenter. Although public cloud computing is a low-cost, flexible, and reliable alternative for organizations, businesses are reluctant to implement this technology. This exploratory research investigates issues that contribute to the slow adoption of public cloud technology platforms and compares three leading public cloud providers in the market. The three cloud service providers selected for this study are Amazon Web Services, Microsoft Azure, and Google Cloud Platform. Information was synthesized from academic literature, conversations with cloud computing professionals, and vendor documentation. Analyzing the data in context of the literature confirms that the demand for public cloud services is steadily rising as firms begin to see the benefits of adoption. Analysis of the data strongly suggests that public clouds can provide secure and agile technology at a lower cost. The research highlighted two significant barriers to cloud adoption. Since many business leaders lack the knowledge and experience with public cloud computing technologies, they hesitate to change from their existing technology platform. In addition, there are common misconceptions about secure processing in cloud computing. This research recommends that organizations examine their current IT infrastructure to determine which areas would benefit from cloud adoption. In addition, this research suggests evaluation criterion to support the technology platform decision so that the public cloud provider selected meets the needs of the organization.

Keywords: Cloud Computing, Public Cloud Computing, Cybersecurity, IT Infrastructure
LEAPS OF FAITH: NON-RATIONAL DECISION MAKING IN INFORMATION SYSTEMS PROJECTS

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ABSTRACT

Despite over 50 years of practice and an abundance of research into its processes, the performance of information systems (IS) project management continues to be fraught with the complex and multifaceted problem of project failure (Carlton, 2014; Hughes, et al., 2016). A prominent approach to addressing this intractable problem in the IS project management literature is the notion of “rational controls” or the logical linkage of clearly defined project outcomes to equally distinct and narrowly construed project processes. This is evident in the two main approaches on project management advocated in extant Project Management Body of Knowledge (PMBOK) guidelines (i.e. waterfall and agile). In the traditional waterfall approach to IS project management rational control is accomplished by dividing projects into discrete sequential types or processes (e.g. initiation, planning, executing, controlling, and closing processes) that are logically tethered to subsequent project outcomes. On the other hand, in agile project management the role of sequential processes is de-emphasized in favor of a more iterative approach that emphasizes consensus instead of abstract processes (Moran, 2015). In this approach consequently rational control is achieved by emphasizing the collaborative or human aspect of project processes and highlighting the logical linkage between these collaborative processes and their subsequent outcomes.

While the two approaches to project management represent divergent schools of thought regarding the control of projects they are both based on a common reliance on rational processes. As is evident from the persistent problem of IS project failure, however, it is apparent that IS projects tend to deviate from their designed rational trajectories. Indeed, the obstinacy of this challenge suggests an enduring gap between the practice of IS project management and academic theorization of these processes. A potential explanation for this gap is the prevalent application of rational frameworks to the study of what in practice could contain significant amounts of non-rational activity (Hirschheim & Newman, 1991). Rational decision-making is based on a systematic collection and assessment of relevant information, and usually follows a formal, lengthy step-by-step process, while non-rational decision making relies on non-conscious, intuitive actions and patterns as well as on feelings and emotions and leads to rapid decisions (Calabretta et al., 2016; Guttierrez & Magnusson, 2014).

Non-rational decision making is not inherently bad – in fact, this type of decision approach is extremely useful, by itself or in combination with rational approaches, in projects that are characterized by complexity, uncertainty, time pressures, or innovation with new technology.
platforms or for new markets (Calabretta et al., 2016; Gutiérrez & Magnusson, 2014). Many IS projects exhibit at least some of these characteristics. One approach (rational) to handling uncertainty in such projects is to focus attention on the facts (or what is known) and to use this knowledge as a platform for embarking into the unknown. Often, however, the “facts” are considered insufficient due to the novelty and complexity of an IS endeavor and decision makers have insufficient time or resources to conduct the research required to unearth the new facts or acquire the prerequisite knowledge. Decision making under these circumstances would be necessarily non-rational (or non-fact based), but they could involve deliberation and choice. Examples of such deliberation include decisions that weigh the ‘ethos’ (or moral/ethical rectitude) and ‘pathos’ (or emotional pull) of particular courses of action.

In this study we examine the role that non-rational decision making plays in complex IS projects that are characterized by large amounts of uncertainty. We apply the lens of rhetorical theory to examine the discursive structure of non-rational decision making entailed in several enterprise systems implementation endeavors. The study contributes to the literature on IS project management by shedding light on a decision-making method that has been traditionally ignored in the literature, and exploring how this method is used in practice.

**Keywords:** information systems (IS), project management, rational decision making, non-rational decision making.

**REFERENCES**


Managing information security investment under mutual information sharing environment

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We study the relationship between information security technology management decisions of a firm and security related information exchanges with other firms. We use stochastic modeling and industry data to reach conclusions on the optimal levels of security information to share as part of a firms investment portfolio for information security technologies. The findings of our study show the incentives of information sharing in different sized firms from different industry organizations.
Smart Data Modeling

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ABSTRACT

The purpose of this research is to investigate the synthesized data modeling of structure and unstructured data to provide an information platform for business intelligence analysis. Although there have been advances in information technology, most organizations do not have highly developed systems for delivering information to managers and other users. Modern organizations are often described as having an ever increasing amount of data but only have a fraction of the information they need. The gap between the data available and the information required may be addressed with appropriate data modeling. Organizations have created uncoordinated and inconsistent databases by independently developing many of their information systems and the supporting databases. In addition, systems are developed to support operational processing to support the commerce activities of the business. The valuable structured and unstructured data captured during operations can also support decision making when modeled appropriately. This research investigates a collection of real-world datasets of related structured and unstructured data and generates a list of business intelligence goals for discovery based on the relevant datasets. The structured and unstructured data are combined and a data model is developed. Based on the data model, a repository is built that contains both structure and unstructured data. Business intelligence information is extracted from the maintainable database environment based on the real-world datasets. Key findings and recommendations on the data modeling of structure and unstructured data are reported.

Information Technology, Data modeling, Structured Data, Unstructured Data, Business Intelligence.
Student Perceptions of SAP ERP System on Ease of Use, Playfulness and Anxiety

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Enterprise resource planning (ERP) systems are “software systems that automate and integrate many or most of a firm’s business processes” [1]. SAP is the market leader in commercial ERP systems. More than 3,100 academic institutions in over 106 countries participate in the SAP University Alliances program [2], which enables them to incorporate SAP ERP software into their curricula by partnering to provide students with a better understanding of business processes and build skills of SAP ERP system. While many students have come to learn about SAP ERP system, it seems that little is known about how they perceive the system as they gain more experiences with the system.

This study attempts to examine the perceptions of students toward SAP ERP system regarding ease of use, playfulness, and anxiety associated with the system. Perceived ease of use is defined as the extent to which a person believes that using a technology will be free of effort [3]. The technology acceptance model [4] posits that perceived ease of use is an important determinant of an individual’s intention to use the system [5]. We hypothesize that students are likely to perceive SAP ERP system to be easier to use as they gain more experiences with the system. Computer playfulness refers to an individual’s tendency to interact spontaneously with a computer [6]. We hypothesize that students are likely to perceive SAP ERP system to be more playful as they gain more experiences with the system. Computer anxiety is defined as the apprehension or
fear that results when an individual is faced with the possibility of using a system [7]. We hypothesize that students are likely to feel less anxious when using SAP ERP system as they gain more experiences with the system.

Data was collected from a survey of 60 undergraduate students who took a course on ERP system and used course materials provided by the SAP University Alliance program. Table 1 shows the survey instrument used to measure the study variables and their items. Students filled in the same survey at two points of time. The first survey was administered in the third week of the semester after students learned the basics of SAP ERP system and practiced with the system for one business process - “sales and distribution.” The second survey was administered in the last week of the semester after students practiced with the system for other business processes including “materials management,” “production planning,” “warehouse management,” “financial accounting,” and “controlling.” The interval between the first and second surveys is twelve weeks during which students had significant exposure to SAP ERP system through various course works. The main purpose of the same survey at two different points of time was to measure how perceptions of students on SAP ERP system change as they gain more experiences with the system.

Data collected will be analyzed in the following two steps. First, the factor analysis will be performed on the ease of use, playfulness and anxiety items to see the appropriateness of the psychometric properties of the measures. Second, the effects of system experience on ease of use, playfulness and anxiety will be explored through an independent samples t-test on the two sets of data collected at two different points of time.

The main results of this study will be the identification of the extent to which students perceive toward SAP ERP system regarding ease of use, playfulness and anxiety, and the identification of any effects of system experience on ease of use, playfulness and anxiety. On a
practical level, such understanding of student perceptions toward SAP ERP system before and after gaining significant experiences with the system will prove a helpful viewpoint for those who want to create a successful learning environment that can cultivate playfulness and reduce anxiety. On a theoretical level, the results are expected to contribute to studies on the technology acceptance model and studies on ERP systems.

Table 1. Measures of the Study Variables

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<th>Strongly agree</th>
<th>Strongly disagree</th>
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<td></td>
<td>1</td>
<td>2</td>
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<tr>
<td>Ease of use (adopted from [3])</td>
<td>Learning to use SAP is easy for me.</td>
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<td></td>
<td>I find it easy to get SAP to do what I want it to do.</td>
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<td></td>
<td>My interaction with SAP is clear and understandable.</td>
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<td></td>
<td>I find SAP easy to use.</td>
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<tr>
<td>Computer playfulness (adopted from [8])</td>
<td>Spontaneous</td>
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<td></td>
<td>Unimaginative</td>
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<td>Unoriginal</td>
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<td></td>
<td>Uninventive</td>
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<tr>
<td>Computer anxiety (adopted from [9])</td>
<td>SAP does not scare me.</td>
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<td>I have lots of self-confidence when it comes to working with SAP.</td>
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<td></td>
<td>I get a sinking feeling when trying to use SAP.</td>
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<td>I would feel comfortable working with SAP.</td>
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<td>Generally, I feel okay about trying to process a new transaction in SAP.</td>
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<td>I am no good with SAP.</td>
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<td>I am not the type to do well with SAP.</td>
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<td></td>
<td>I do not feel threatened when others talk about SAP.</td>
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THE INTERNET OF THINGS AND BUSINESS OPPORTUNITIES

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INTRODUCTION
The Internet of Things (IoT) has the potential to increase quality of life, heighten performance of systems and processes, and save valuable time for businesses and people. Common objects and devices are being linked with Internet connectivity and have capabilities for data analytics that affect day-to-day experiences of both individuals and businesses. The IoT is intended to do the following:

• Connect both inanimate and living things. Any device with an on and off switch can be connected to the Internet and/or to each other. Examples include cell phones, coffee makers, washing machines, headphones, lamps, wearable devices (e.g., fitbit), etc. They can also include living objects. Your refrigerator may know what you want to eat based on your weight loss plan or the time of day you arrive home (Xiao, Guo, Xu, & Gong, 2014).

• Use sensors for data collection. The objects will contain sensors that will collect data such as motion, location, vibration, and temperature (Ding, Cooper, Pasquina, Fici-Pasquina, 2011). Further, these sensors will connect with each other and to systems to make sense of the data or at least present the data from the sensors (Albrecht & Michael, 2013). As a result, people or companies will have a lot of new information (Li & Xiong, 2013).

• Allow equipment to communicate. Now objects can communicate with each other (Ding, et al., 2011; Albrecht & Michael, 2013). Imagine your alarm clock goes off at 5:00 a.m. than...
notifies your coffee pot to start brewing coffee. Or in the office, they automatically re-order when supplies run low.

- The Internet of Things (IoT) is a prominent topic in today’s world of technology that is constantly growing and evolving. This is a concept in which everyday objects are connected to the Internet, allowing them to send and receive data. In order for the IoT framework to be successful, wireless networks are essential because sensors need to be able to link without the limitations of physical wiring. The benefits are almost infinite as IoT devices and applications are altering the ways that people live and work on a day-to-day basis by saving time, making resources more efficient, and opening new doors to development and innovation. The far-reaching use of IoT products and devices shows the high capacities of automated home and work appliances, energy management, health monitoring gadgets, enhanced traffic systems, and countless more improvements within institutions and cities.

- The ultimate goal of IoT is to enable things to be connected at any time or place, by anything or any person who is using the network. Moreover, CEO of Cisco, Chuck Robbins, predicts that 50 billion devices will be connected to the Internet by 2020 (Vanian, 2015). The success of certain IoT devices will really be contingent on the ways that security and privacy matters are approached in the development stages as well as how those types of issues will be addressed if the concern becomes a reality. This paper will discuss and give examples of specific devices or applications used within the spectrum of Smart Health, Smart Cities, and Smart Living. Each section will give an overview of the industry, description of specific examples, and any further limitations or implications that it may have.

- As with the majority of information systems (IS), the Internet of Things depends on a variation of different hardware, software, and architectures. According to Whitmore,
Agarwal, and Xu (2015), technology can be classified into three sub-categories. However, these are not exclusively separate from each other because architecture is developed and forms alongside software and hardware.

- In regards to hardware, the bulk of its foundation has already been around for some time now so this allows IoT to build upon its present framework. As Whitmore, et al. (2015) illustrates, within the sub-sub-category of hardware, there are some important infrastructures to distinguish, such as RFID (Radio-Frequency Identification), NFC (Near Field Communication) and Sensor Networks. Furthermore, software must continue to evolve by using middleware to sustain interoperability between various unrelated devices and examining the data produced by them. The domain for what application topics IoT can influence is virtually endless but all come with the trials of security and privacy that need to be addressed to safeguard IoT acceptance and dissemination. As previously noted, this research will focus primarily on matters of IoT in healthcare, within cities or municipalities, and the overall way of life in the midst of technology with an emphasis on the benefits and challenges of each.

**HOW DOES THE IOT WORK?**

It all starts with “smart objects” which are objects that can communicate with people and other smart objects. It includes both physical interaction and virtual computing interaction. Smart objects are created when RFID tags or sensors are embedded into non-smart physical objects (Ashton, 2009). The IoT is not a technology within itself but a conglomerate of complementary technologies and capabilities that work together to bring together the virtual and physical world (Martin, 2015). These capabilities include:
• Communication and cooperation: Wireless technologies including Wi-Fi and Bluetooth give objects the ability to network with the Internet.

• Addressability: Objects need to be located and addressed via discovery, look-up, or name services. Therefore, they can be interrogated or configured remotely.

• Identification: RFID, NFC, and optically readable bar codes uniquely identify objects so that data can be retrieved from a server related to the particular object. Assumes the object is connected to a network.

• Sensing: Information is recorded from objects with sensors; the object may forward the information or react directly to it.

• Actuation: Objects can manipulate their environment by converting energy into motion and control processes via the Internet.

• Embedded information processing: Processors and storage capacity can be used to process and interpret sensor information or give products a “memory” of how they are used.

• Localization: GPS, mobile phone networks, Ultra-Wide band or radio beacons allow objects to know their physical location or be located.

• User interfaces: Allow objects to communicate with people i.e. smart phone.

BUSINESS PROBLEMS THAT IOT IS INTENDED TO SOLVE

The IoT creates huge opportunities for the economy and individuals. The IoT has no boundaries and will impact every business and person. With new devices connecting into company’s systems, new types of data will be accessible. At least three of the major benefits are communication, control, and cost savings which lead to transformed business processes, improved customer retention, new business models, and an increase in the quality of life. In a
study done by McKinsey Global Institute (2015), it predicts that the IoT has potential economic impact of $3.9 trillion to $11.1 trillion per year in 2025 – the value of this impact would be equivalent to approximately 11% of the world economy in 2025. The study goes on to describe how the IoT will impact nine settings:

- **Human.** IoT impacts humans in two ways, health and fitness. Using connected devices patients with chronic conditions can be continuously monitored. Monitoring conditions can lead to increased adherence to prescribed therapies, and avoidance of hospitalizations. Remote services such as emergency detection and first aid can be used. Secondly, human productivity can be increased with technologies such as augmented-reality devices, job redesign or processes efficiencies, and allow mobile workers to be more connected.

- **Home.** There is a growing trend for IoT devices in the home including thermostats, appliances, and self-guided vacuum cleaners. Your refrigerator and cabinets may be able to talk to your phone and let you know what you need to buy at the grocery store. A thermostat could be linked to a garage door opener and adjust the temperature to that persons liking. Leading to chore automation, life-style improvement, energy management, and increased security.

- **Retail environments.** Retailers can gain efficiencies in checkout automation, layout optimization, smart customer relationship management (CRM), in-store personalized promotions, and the prevention of inventory shrinkage. Resulting in increased customer satisfaction, revenue, profit, and working capital optimization.

- **Offices.** The main benefits are increased security, utility management, and improved productivity.
• Factories. Predicted to gain the largest value from productivity improvements including labor and energy, improvements in maintenance, working capital optimization, and employee health and safety.

• Worksites. Can benefit from operational improvements, improved equipment maintenance, and overall improvement in human health and safety.

• Vehicles. Monitor and improve the performance of planes, trains, and other vehicles. Your car can become a mobile hotspot allowing passengers to surf the web or watch a movie. Over the air updates can be downloaded to avoid visits to the dealership. Safety and security features can automatically alert emergency services when an accident occurs.

• Cities: Can benefit from the IoT in four main areas, transportation to manage traffic flow, public safety and health from increased air and water quality, resource management, and service delivery.

• Outside: Improve routing and tracking of ships, airplanes, and other vehicles.

**OBSERVATION AND FUTURE DIRECTION**

Throughout all the readings and research, one recurring notion that seemed to always come up and be acclaimed is that the Internet of Things has the potential to dramatically improve the lives of people and organizations through a wide variety of domains and aspects. The proficiencies accessible by the IoT not only can save individuals and businesses resources, but can also assist with making difficult assessments and decisions about a particular issue on hand. It is well known that IoT progresses on foundations that have already been built and enhances the way present technologies, like RFID and sensor networks, work and communicate with other devices. According to Whitmore, et al. (2015), one future direction for IoT is the “Web of Things,” which
is a concept of using the World Wide Web to completely assimilate smart objects. This could enhance the interoperability of different devices in such a way that it would support developers to create applications in a much simpler way. Furthermore, some researchers suggest applying the Web 2.0 concept of a mashup, where an application taps into an assortment of web resources for information, but instead, harnessing it to physical devices rather than applications.

These discoveries initiate a few more personal observations and inquiries. For instance, it will be interesting to see if the Internet of Things will persevere in a world of ever-changing philosophies to become a permanent technology, or if it will evolve into a different paradigm. A couple different future avenues of research could be examining how IoT measures up into the “Big Data” movement or maybe looking into some uncommon domains that IoT has yet to encounter. Perhaps diving into the IoT business models that assist and promote global commerce could be an inquisitive direction as well. Nevertheless, only time has the capacity to show the potential and reality of IoT to reshape our world of technology.

CONCLUSION
The IoT creates huge opportunities for the economy and individuals. The IoT has no boundaries and will impact every business and person. With new devices connecting into a company’s systems, new types of data will be accessible. It will become a tool with advanced technology in sensing, controlling, communications, and in delivering solutions from huge amounts of gathered data. This will change lifestyles and business models from today. We cannot predict the exact outcomes. IoT’s potential success in the market place is inevitable as the world requiring for greater connectivity and benefits of IoT is limitless to vast majority. Companies looking for
more efficient ways to operate and provide services. Hospitals and patients are seeking for earlier detection of chronic diseases through IoT indicators. People are looking for ways to ease their lives. It is certain that IoT will have enormous impact on consumers and businesses. IoT is still at an early stage of development. Even though IoT problems of privacy and security arise, with the help of research communities and companies investing in R&D, new solutions will be developed to help build trust in consumers for new IoT technologies. A common understanding of IoT benefits will help fasten the advancement of the IoT market for both enterprises and consumers.

Explaining the functions of one device or method with the field of Smart Health, Smart Cities, and Smart Living in this paper is only a minuscule scratch on the surface in regards to the wide range of products and services that are available with IoT capabilities. As with all things, there are benefits and limitations that naturally come with every device, no matter the production. As IoT devices serve as solutions to a variety of countless things, there is always a risk of a security breach, regardless the industry. IoT applications must be able to detect and prevent system compromises and should have multiple layers of protection to ensure that hackers are kept out. Monitoring should be a constant and continuous process because even the most safeguarded systems will always have some vulnerability for a motivated hacker. However, the most vital processes are the damage control procedures set in place for if a breach does in fact transpire. The organization behind the IoT device or application must be able to mitigate the losses and recover as fast as possible (Gantait, Patra, & Mukherjee, 2016). The AliveCor Heart Monitor, the sensors used for waste management, and the Belkin WeMo Light Switch are three devices from completely different industries with very little in common other than the fact that they are
connected to the Internet wirelessly and assist people in their own ways. The Internet of Things will remain a notion that will allow innovators to continue to grow and exceed the boundaries of technology.

The convergence of sensors, hardware and connectivity are what power the IoT. Copious amount of data and consumer demands for continued optimization, it is obvious that IoT is becoming a permanent part of our technological landscape. Subsequent connections and almost-unlimited amount of data have moved devices beyond a simple reporting function to smart tool of enabling better and quicker decision-making. IoT drives business both in consumer and enterprise applications, representing trillions of dollars in potential economic impact. While taking advantage of the multitude of opportunities IoT represents, we must also keep an eye on the potential problems and limitations. Security, privacy, incompatibles, and problems in data movement and storage are primary concerns. Managers today and in the future will need to address these issues.

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Incentive Strategies for Facilitating Knowledge Sharing on an Enterprise Social Network

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Abstract

This paper presents and studies an analytical model of knowledge transfer on an enterprise social network in organizations. We explore the design of incentive schemes to facilitate knowledge sharing on the network based on the specific type of a knowledge provider. Our research provides valuable insights for practitioners to promote the success of their enterprise social networks and lays the foundation for future research.


Introduction

Social networks are becoming popular for enterprises in recent years as they have great economic implications (Jackson, 2007). Different from external social networks such as Facebook, internal social networks have been developed and implemented by many companies for specific purposes (Trees, 2013). For instance, IBM designed and developed Beehive (later called SocialBlue), an internal social networking site, within IBM's intranet. Beehive was implemented to help employees make connections with their current and past coworkers for sharing ideas (DiMicco et al., 2005). Capgemini implemented Yammer in 2008 as its enterprise social network to allow information sharing and employee connection (Riemer, 2012).

Due to the growing popularity and success of social networks in knowledge management, researchers have started to explore the relationship between social networks and knowledge sharing in organizations. For instance, Cross, et al. (2001) evaluate and investigate the important characteristic of knowledge workers that can be used to improve knowledge workers’ abilities of creating and sharing knowledge in social networks. Based on a framework integrating three social capital factors including social network, social trust, and shared goals, Chow and Chan (2008) examine their relationships and find that a social network and shared goals significantly contributed to a person's volition to share knowledge, whereas the social trust has no direct effect on the attitude and subjective norm of sharing knowledge. Panahi et al. (2012) discuss social media concepts and identify five requirements of creating and sharing tacit knowledge in social media sites: social interaction, experience sharing, information relationship and networking, observation, and mutual trust. Helms et al. (2013) apply the technique of Knowledge Network Analysis and develop a Knowledge Sharing Environment Model to identify knowledge sharing bottlenecks in social networks through a case study. Using social network mapping and analysis
method, Cudney et al. (2014) study the ways to develop a knowledge management system and the approaches to encourage knowledge sharing in a healthcare organization.

Nevertheless, very few studies have explored the incentive strategies of facilitating knowledge sharing in enterprise social networks. Our paper makes an attempt to address this gap by studying incentive schemes to motivate workers’ knowledge sharing and learning in the enterprise social network.

Specifically, our study explores the following research questions. First, what are the critical factors in modeling the relationship between an enterprise social network and knowledge transfer within organizations? Second, how should companies effectively design incentive schemes to facilitate knowledge sharing in such networks? Finally, what are the strategies that companies can implement to supplement or substitute the incentives that reward knowledge sharing on an enterprise social network?

The rest of the paper proceeds as follows. Next section presents an analytical model of knowledge transfer in an enterprise social network. The third section discusses the preliminary results and their insights. The last section concludes the paper.

**Model**

This section presents our analytical model and the organizational decision problem for designing the incentive schemes.

We consider an enterprise social network used by a firm to facilitate knowledge transfer among \( n \) knowledge workers within the organization. Each worker in the network has a level of knowledge that she is able to share with her followers. Sharing the knowledge with other workers will result in a cost for a knowledge provider. As it is common in prior literature (e.g.,
Sundaresan & Zhang, 2016), we assume that a worker’s sharing cost increases with the amount being shared and decreases with the worker’s knowledge level. To help offset a worker’s sharing cost, the firm offers an incentive for each knowledge provider in the network.

Figure 1: Timeline of the model

Figure 1 summarizes the four stages in the model. We assume that all the information is transparent so the sharing costs and the network structure are observable to the firm. First, the firm announces an incentive scheme to reward knowledge sharing. Second, workers share knowledge and learn through the social network. Third, workers work on projects, generating output. Finally, sharing rewards are allocated to knowledge providers in the network based on the pre-announced incentive scheme.

To simplify our analysis, we assume there are two types \((k^H, k^L)\) of knowledge workers in the firm: high-knowledge and low-knowledge workers. In addition, we differentiate two types of high-knowledge workers with respect to their sharing costs \((C^H, C^L)\): high or low. Therefore, the firm designs the incentive scheme \(s(\cdot)\) based on the type of the knowledge worker and the number of her followers (the network structure), i.e., \(s(\cdot) = s_i(k, \theta_i, C_i)\), where

\[\begin{array}{l}
\text{The firm announces an incentive scheme for rewarding knowledge sharing.} \\
\text{Workers engage in knowledge sharing and learning on the social network.} \\
\text{Workers apply their knowledge in projects, generating an output.} \\
\text{The firm allocates sharing rewards according to the incentive scheme.}
\end{array}\]
\[ i = 1, 2, \ldots, n, k_i = k^H \text{ or } k^L, \quad C_i = C^H \text{ or } C^L, \quad \text{and } \theta_j \text{ represents the number of followers for a knowledge worker } k_i. \]

In summary, the firm’s decision problem is to design the incentive scheme \( s(\theta) \) to maximize its total payoff facilitated by the total knowledge sharing on the enterprise social network, i.e.,

\[
\max_{s(\theta)} \pi = f(K) - \sum_{i=1}^{n} s_{ij}(k_i, \theta_i, C_i)
\]

subject to

\[ \pi_j \geq 0, \]

where \( K \) is the vector representing the knowledge level of each worker, i.e. \( K = \{k_1, k_2, \ldots, k_n\} \) and \( f(K) \) measures the contributions of workers’ knowledge to the firm.

**Outline of Analysis**

Following upon the discussion of our analytical model, we next present some of the preliminary results and discuss the implications of these results.

Since we only consider two types of knowledge workers with respect to the knowledge level, high-knowledge workers’ decision is to decide whether or not to share their knowledge to the low-knowledge workers based on the incentive scheme announced by the firm. Low-knowledge workers do not make any decisions and will just passively learn whatever is shared with them to enhance their knowledge level. Therefore, \( s(\theta) \) will always be zero for low-knowledge worker.
Therefore, the incentive scheme will be targeting, if at all, the high-knowledge workers. We next differentiate high knowledge workers into two groups with either a low or high connectivity level, then all the high knowledge workers will fall into one of the following four categories.

<table>
<thead>
<tr>
<th>Types of a high-knowledge worker</th>
<th>Connectivity Level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>High</td>
</tr>
<tr>
<td>Sharing Cost</td>
<td>High</td>
</tr>
<tr>
<td></td>
<td>Low</td>
</tr>
</tbody>
</table>

Table 1: Four types of a high-knowledge worker

The active-efficient high-knowledge workers are those who are active on the enterprise social network and are adept in sharing their knowledge over the network. In contrast, the two types (active-inefficient and passive-efficient) categorize those high-knowledge workers who are either passive on the enterprise social network, or inefficient in disseminating their knowledge over the network. Finally, the passive-inefficient high-knowledge workers do not actively participate in activities on the network and are inefficient in coding and sharing their knowledge with other workers.

Based on the four types of high-knowledge workers, we first explore the benchmark case in which each low knowledge worker is at most connected with one high-knowledge worker, but each high knowledge worker can connect with several low-knowledge workers. The following proposition demonstrates how the incentive scheme should be designed for high-knowledge workers.
**Proposition 1.** When each low knowledge worker is at most connected with one high-knowledge worker, the firm should offer an incentive to each high-knowledge worker that covers the worker’s sharing cost.

Proposition 1 indicates that in the special situation when each low-knowledge worker can only learn from one high-knowledge worker, then all the high-knowledge workers should be rewarded in order to facilitate the knowledge transfer so as all the knowledge workers can reach the same knowledge level as those of high-knowledge workers.

We next investigate the incentive structure when each low knowledge workers can connect with multiple high-knowledge workers, and each high knowledge workers can connect with multiple low-knowledge workers. The following proposition illustrates the incentive scheme that the firm can implement.

**Proposition 2.** When each low knowledge workers can connect with multiple high-knowledge workers, and each high knowledge workers can be followed by multiple low-knowledge workers, the incentive structure will give the active-efficient high-knowledge workers the highest priority and the passive-inefficient the lowest priority.

Proposition 2 suggests the priority of the incentives with respect to the four types of high-knowledge workers. Active-efficient high-knowledge workers should be motivated to share knowledge over the network with the highest priority, whereas passive-inefficient high-knowledge workers with the lowest priority. The other two types of high-knowledge workers will receive an intermediate priority of incentives, depending on the specific structure of the enterprise social network.
Based on the results summarized by Proposition 2, two specific strategies can be developed to supplement or substitute the incentives so as to facilitate the knowledge sharing over an enterprise social network. The first strategy is to reduce the sharing costs of workers on the social network and the second one is to improve the activeness of knowledge providers on the network. Many companies have already implemented these strategies to promote knowledge sharing on their enterprise social networks. For instance, Lenovo rewards users of its internal social network, Lenovo Social Champions, with points in exchange for various actions including knowledge sharing. In addition, Lenovo develops the campaign of Employ Advocacy to keep employees engaged in its social network (Pearson, 2015). BASF created its internal social network, connect.BASF, using cutting-edge technologies. The platform makes it easier for users to create profiles, connect with other workers, share and edit files with others (Krooß, 2013).

**Conclusion**

Prior research has recognized the important role of social networks in knowledge management, but there lacks research in exploring the design of incentives in enterprise social networks for knowledge transfer. Our paper addresses this gap by making an attempt to explore the design of incentive schemes for rewarding knowledge sharing on an enterprise social network. In particular, we analytically model an enterprise social network in which workers can share their knowledge and learn. In addition, we categorize a knowledge provider into four types: active-
efficient, passive-inefficient, active-inefficient, and passive-efficient. Finally, we propose the incentive strategies that firms can implement to effectively reward knowledge providers so as to enable knowledge sharing on the network.

This study is our preliminary attempt in analyzing the incentive issues for promoting knowledge sharing on enterprise social networks. Future research will make less restrictive assumptions in our modeling framework to comprehensively investigate the incentive schemes. For instance, type of a knowledge worker may not be observable, which will change the design of incentives. In addition, the incentives offered by firms may dynamically impact the network structure, which should also be considered when the incentive schemes are designed. Our research provides some insights for practitioners to implement appropriate strategies to promote the success of their enterprise social networks and lays the foundation for future research in this field.

References


9


Lemons to Lemonade: Literature Gap Analysis of Knowledge Management Technology Solutions in Parents’ Journey with Childhood Cancer

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ABSTRACT

Decisions involving human health require access to accurate and timely knowledge and information. Introducing parents who have recently received news of a child’s diagnosis with cancer to a Knowledge Management portal may provide an opportunity to contribute to caregiver mental health throughout the child’s treatment and result in improved outcomes for the family unit. Using personal experience as a motivation to develop grounded theory while removing personal bias (Glaser and Strauss, 1967), this study aims to create and leverage a knowledge base to share parent experience following a child’s diagnosis. The goal of the study is to generate a grounded theory and best practices for physicians and other health care providers who are interested in ensuring patient adherence to protocols and for caregivers who must be well informed to enable execution of medical provider instructions. Children rely on this coordinated support system and unlike adults, depending on patient age, may not have the maturity to understand the consequences of medical decisions, nor feel the emotional burden of the caregiver.

In this regard, to achieve the main goal, this study provides an extensive review of current practices, applications, and methods. The format is a meta-analysis of the current literature in this focus area to achieve clarity about gaps in the current research and support subsequent research to fill those gaps (Creswell, 2013).
The search for understanding medical and non-medical information is inevitable for any parent who has heard the words “Your child has cancer.” Family and friends will search many sources from doctors and family history to public and private Internet references to understand the diagnosis in the context of their situation. The problem is that many of the sources are unreliable, resulting in misinformation and stress. This problem will be addressed by answering this research question: how can current knowledge management methods facilitate the capture and leveraging of parent reporting on actual experience as well as facilitate the usage and ensure the reliability of other sources to enable best care opportunity for the child survivor? The focus of this research will be to understand the key variables proposed in Figure 1: technical, socio-cultural, economic, and ethical parental concerns.

Figure 1: Key Variables
This meta-analysis addresses the problem statement by answering the research question via focus on previous literature. Sources of knowledge include non-medical views from those who have had similar experiences during treatment protocol, medical providers delivering information to parents that has been filtered by professionals, and parents’ family and peers attempting to share useful advice. The literature review is anticipated to provide confirmation that successful patient outcomes also depend on the emotional and social health of the family system to result in long term success. Opportunities to capture knowledge in a relevant and reliable manner to further the health and welfare of families will be reviewed as will previous cases where knowledge management methods were effectively applied to address similar situations. In doing so, this research may refute recent claims by Davenport (2015) and Skyrme (2011) that knowledge management is no longer relevant. Alternately, this research aims to support Lee’s (2015) assertion knowledge management has evolved into a foundational capability, in this case for the care and support of medical practitioners and caregivers. It is expected that the research will demonstrate the applicability of seminal knowledge management concepts including the “spiral” of Nonaka’s (1991) SECI Model about the socialization, externalization, communication and internalization of knowledge, the concept of communities of practice (Hislop, 2013) and cyber Ba (Nonaka; Hislop). Parallels with the learning organization theories advanced by Senge (2006) and Pedler, et al. (1997) will also be explored. These steps will ensure this meta-analysis begins to address the study’s problem statement and research question while understanding how its findings fit into the context and support of advancing knowledge management.
**Keywords:** Technology Management, Knowledge Management, Decision Making, Quality Systems, Healthcare, Pediatric Oncology

**Reference List**


The Effects of HR Diversity Management on Employee Knowledge Sharing: A Replication and Extension Study

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Abstract

Replication evidence has long been considered a cornerstone by which claims from research that touts to provide a novel theoretical contribution to the current knowledge base of a given research stream are evaluated. However, increased pressure on researchers to provide a novel theoretical contribution has given rise to a condition where replication research remains rare in the organizational sciences especially in the area of knowledge management. The purpose of this study is to conduct a conceptual/constructive replication (i.e., hypotheses and results evaluated using alternate methods of sampling, measurement, and data analysis) of the Shen, Tang, and D'Netto (2014) study on the effects of human resource diversity management on employee knowledge sharing and the mediating and moderating variables underlying this link. In the original study, surveys were used to collect the data which was analyzed by conducting multilevel analyses using hierarchical linear modeling (HLM) and mediation analysis. Replication of significance effects, lack of significance effects, effect size, and whether the replication's conclusions were consistent or inconsistent with the original study will be assessed. The expectation of this replication study is to identify potential biases in the original study and serve as a basis for confirming or disconfirming prior findings which could potentially provide a basis for generalization beyond the original study's project setting.
THE SOCIAL DIMENSION OF KNOWLEDGE MANAGEMENT:  
A QUALITATIVE ANALYSIS OF MULTIPLE CASES OF SOCIAL-
MEDIA-BASED KNOWLEDGE SHARING

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ABSTRACT

Social media continue to proliferate. This paper presents a qualitative analysis of twelve (12) cases of social-media-based knowledge sharing. The analysis reveals six (6) categories of knowledge sharing in the social context. The analysis indicates that personalization of the organization entities and socialization of the participation on social media for knowledge sharing are two key success factors. The findings suggest that the social dimension, which has been absent from the traditional knowledge management models, broadens the scope of sustainable knowledge sharing practices for the digital society.

EXTENDED ABSTRACT*

1. INTRODUCTION

Social media have been widely used in the society for social communication (Morehouse and Crandall, 2014), business (Berkman, 2013), healthcare (Harris, Mueller, and Snider, 2013), society (Collins et al., 2013), education (Field, Elbert, and Moser, 2012), politics (Shiraz, 2013), and government (Magro, 2012). One of the important motivations of people to use social media is knowledge sharing (Panahi, Watson, and Partridge, 2013).

Social-media-based knowledge sharing has raised various interesting issues for the knowledge management community (Vuori and Okkonen, 2012; Chua and Banerjee, 2013). Generally, social media are considered to be tools of communication or collaboration for the knowledge workers of the organization to implement the knowledge management process. However, social media play a significant role in providing massive diversified information in the social context beyond serving a set of communication tools for individual organizations. Thus, the social dimension of social-media-based knowledge sharing needs to investigate for knowledge management in the social context. Specifically, the following research questions are important

* To ensure significant differences between the present conference paper and a potential journal publication based on this study, the authors submit this extended abstract to the conference proceedings. The full-length paper submitted for the oral presentation at the 2017 NEDSI Conference is available on request for academic knowledge exchange.
to knowledge management: What types of knowledge do people share by using social media? What are the outcomes of knowledge sharing in successful cases, and what are the success factors for those cases? This paper provides a case analysis of twelve (12) cases social-media-based knowledge sharing. It reveals six (6) categories of knowledge sharing in the social context. The analysis also suggests that the scope of personalization and socialization in social-media-based knowledge sharing are broader than that in traditional knowledge management.

2. METHODOLOGY

To identify cases of social-media-based knowledge sharing, a literature review was conducted. The tools used for the literature review were the ABI/INFORM Global database and the Google search engine on the Internet. Twelve (12) cases were found.

This study is an induction process with the data triangulation tactic (Jick, 1979) which combines multiple cases to generate a generalized conclusion. The participants of the case analysis process were a group of nine (9) MBA students who were taking a knowledge management course coordinated by one of the authors. The knowledge management course uses Becerra-Fernandez and Sabherwal’s textbook (2015). The textbook covers abundant terms and models of knowledge management which were used as a guidebook of coding in this study. These participants conducted a so-called Joint Analytical Process (JAP) (Wang and Wang, 2011) to make qualitative data analysis, as explained later in this section. A general guide for the analysis of multiple cases (Yin, 2003) was set for the study.

Qualitative data analysis has been a central issue of case studies (Miles and Huberman, 1994; Tashakkori and Teddlie, 1998). Coding is often applied as a tool to facilitate discovery and further investigation of the qualitative data (Kelle and Seidel, 1995; Straus and Corbin, 1998). There are few guidelines for coding with multiple cases. Semantics and pragmatic meanings of qualitative data with multiple cases more or less depend upon individual analysts’ interpretations of the cases. In the present case of induction analysis without a hypothesis, computerized coding process is difficult to apply. Thus, coding of the transcripts was done manually. The values coding method was applied. Each segment related to a question in the protocol was labeled with a “code” which was a keyword or a short phrase. Each team interpreted the diversified semantics and pragmatic meanings in multiple cases and made initial coding, and presented the codes in subsequent cross-teams meeting. All disagreements on coding were resolved at the cross-team meetings resolved.

3. FINDINGS

The case analysis revealed six (6) categories of social-media-based knowledge sharing: social survey, social searching, social trends awareness, social campaign, social learning, and social attention appealing.

The qualitative case analysis reveals that (1) personalization of the organization entities, and (2) socialization of the participation on social media for knowledge sharing are two key success factors. These two key factors for knowledge sharing have not been addressed in the extant knowledge management models. In traditional knowledge management, knowledge sharing is
assumed to take place within the organizational boundaries of control. All knowledge sharing participants form a planned knowledge sharing community to achieve the pre-defined goals of knowledge management. This assumption seems to inherit from the traditional concept of management that management operates through five functions: planning, organizing, coordinating, commanding, and controlling (Stroh, Northcraft, and Neale, 2002). In the cases of social-media-based knowledge sharing, these basic functions of management are no longer applicable because the environment of knowledge sharing in social media is a dynamic society instead of a static organization.

4. LIMITATIONS OF THE STUDY

As a qualitative analysis of multiple cases based on the literature review and subjective understanding and interpretation, the study has its limitations. The analysis of these limited qualitative data could involve biases of the participants. Future studies are needed to improve the findings based on other independent studies.

5. CONCLUSION

This study has collected and analyzed the qualitative data of twelve (12) cases of social-media-based knowledge sharing. The case analysis identified six (6) categories of social-media-based knowledge sharing: social survey, social searching, social trends awareness, social campaign, social learning, and social attention appealing. The analysis indicates that personalization of the organization entities and socialization of the participation on social media for knowledge sharing are two key success factors. The study has suggested that the social dimension of knowledge sharing, which has been absent in the extant knowledge management models, is critical for practicing social-media-based knowledge sharing. Knowledge sharing practices with the critical dimension of socialization can ensure the sustainability of knowledge sharing through personalized engaging the social media community. This study has made contribution to knowledge management by demonstrating that the effectiveness of social-media-based knowledge sharing depends not only on the use of social media as a tool, but also on the people’s competence of social involvement.

REFERENCES


The Design of Eco-Sustainable Dynamic Disassembly Strategy

Objectives: The substantial growth in advanced manufacturing has led to an increasing need for sustainable manufacturing and End-of-Life (EoL) management in order to mitigate the negative impacts on environment and save cost in future production. The research objective of this project is to understand the relationship between the environmental impact and economic cost/benefit of disassembly of EoL products for remanufacturing and reuse, and then to design a dynamic disassembly strategy with optimal environment and economic tradeoffs accordingly. Our approach will be amenable for a wide range of industrial products. Specifically, we will demonstrate our disassembly strategy with the lithium-ion battery of electric vehicle (EV) as it is a typical high energy-embodied industrial product. This research project proposes a novel decision support tool for eco-sustainable manufacturing and EoL management, and aims to help resource allocation in an efficient and responsible way that provides long-term benefits from sustainability and establishes profitability.

The needs: The need for appropriate EoL management has been increasing due to emerging technologies, changes in consumer behavior, and shorter product life cycles. The need is particularly prominent in industries such as consumer electronics, automobile, and semiconductor, etc. Especially, automobile industry has been motivated to reduce the landfills of dissembled auto parts, and establish a new source of parts through product recovery, disassembly, and remanufacturing. In the race to put one million electric vehicles (EVs) on U.S. road by 2020, lithium-ion batteries with high energy-density are used to power the propulsion of the EVs. The value chain of the batteries consists of multiple steps: component production (raw materials); cell production; assembly; integration of the battery pack into vehicle; use phase; and reuse/remanufacturing/recycling. As the Li-ion battery technology is still moderately mature, massive battery returns caused by failures are expected in the next 5-8 years. As such, an enormous challenge as well as a great opportunity coexist in the design of an eco-sustainable EoL disassembly strategy, which not only facilitates the recovery and reutilization of the residual value from the used batteries, but also reduces their negative impact on the environment.

Characterization of the Relationship Between Environmental and Financial Performances

In this research, we investigate a fundamental analytical problem: whether EoL treatment such as disassembly and remanufacturing efforts is rational in both environmental and economic terms. Specifically, can manufacturers gain competitive advantages through taking environmental responsibility? If so, how? This task will test the hypothesis that environmental effort on EoL treatment implies a trade-off with financial performance. Fig. 2 illustrates the existence of an optimal degree of disassembly such that the global optimum is achieved. We propose to develop a novel environmental impact evaluation model that incorporates principle component analysis and multivariate regression to test the hypothesis, and explore the statistical correlation between the two performance measures using historical information. This task will address the complex EoL decision-making by identifying and quantifying the adverse and beneficial effects of disassembly/dismantling on the long-term environmental response.

Dynamic Disassembly Strategy through Risk-Neutral Probabilistic RUL Estimation

We also define the optimal disassembly strategy for EOL products. A typical stochastic EOL return process can be predicted using either convolution-based approximation method or Monte-Carlo simulation, with uncertainty in EoL considered (Fig. 3). Built upon PI’s past successes in modeling degradation behavior of mechanical components and batteries, and in developing prognostics models for
remaining useful life (RUL) estimation, we aim to investigate the condition of individual components in relation to the condition of the whole piece of product. Reliability models will be developed to characterize such relationship (Fig. 4). We also propose a novel modeling method to describe the disassembly process through a probabilistic condition estimation technique, and to determine the degree of disassembly in a dynamic circumstance. The model can be visualized as a disassembly tree with conditional probabilities obtained from historical inspection data and RUL estimates (Fig. 5). For each branch of the tree, the quality probability distribution for each subassembly is on condition of the quality of its “parent” assembly. The success of the stochastic modeling of probability transitions across multiple levels will provide a foundation for evaluating the environmental impact/benefit and financial value of the EoL treatment options, and will enable predictive decision support for dynamic disassembly. To solve this problem with stochastic and partial observable EoL conditions, we will develop an Approximate Dynamic Programming (ADP) to seek for the optimal solutions and their structural properties.
“A Query into the Potential Effects of Samsung’s Recent Smartphone Malfunctions on The Marketability of Other Product Lines”

Southern New Hampshire University

February 11, 2017
"A QUERY INTO THE POTENTIAL EFFECTS OF SAMSUNG’S RECENT SMARTPHONE MALFUNCTIONS ON THE MARKETABILITY OF OTHER PRODUCT LINES"

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I. Introduction

A. Research Statement

This research would appear to be the first study that is taking an empirical approach to answering the research question being asked in this study. The events that have prompted the formulation of the research question are very recent, only taking place slightly over two months earlier. Various articles have been published by various organizations discussing the disaster Samsung has suffered with its Galaxy Note 7 Smartphones which has resulted in the company recalling a large amount of devices as well as granting primary competitors such as Apple a large advantage in the marketplace (Seitz, 2016). Samsung is now also on the receiving end of a class action lawsuit concerning faulty washing machines (Mettler, 2016). All of these events are very recent and relevant to both consumers and businesses today and makes them a qualified topic for research. There has been discussion over whether or not the malfunctions Samsung is experiencing with its Smartphones will cause its other product lines to suffer.

With the release of the latest model in the Samsung Galaxy Note 7 series, the market trends for Samsung have been drastically changed. Although the Galaxy Note 7 had remarkable sales at the beginning of its product launch, the latest model had a hardware issue which caused the smartphone to overheat and in the worst case, blast off causing damage not only to the product but the surroundings as well. This fault was not only detected by mobile phone experts worldwide but also acknowledged by the company as well. The company has announced all of the destroyed machines to be reimbursed; however, the impact of this whole scenario could cause a loss of confidence the buyers have, not only in the Galaxy smartphone series but other products of Samsung as well.
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Farrell, S. (2016) says: ‘Samsung has had £11bn wiped off its shares after the world’s biggest mobile phone maker warned customers not to use its Note 7 model because of the risk of it catching fire.’ It clearly shows how this fault has emerged as a bigger problem. The loss in the share value of Samsung will also induce a lack of confidence in the public stockholders which will affect in the future.

In another article, several brand experts put forward the opinion that while Samsung is certainly having issues with its Smartphones, that the company’s brand is strong enough so that any damage it will most likely be small and temporary, and that, being a company that offers such a wide range of products, Samsung’s various other product lines will probably not suffer (Adgully Bureau, 2016). It should be noted that while the opinions of these experts certainly have value, they are still only opinions and currently there has been no empirical study evaluating the truth of these claims. The hypothesis of this study is actually in direct contradiction with these opinions and is as follows: Recent malfunctions in Samsung’s Galaxy Note 7 smartphone will have an impact on consumers’ intention to buy from Samsung’s other product lines.

B. Purpose of the Study

The objective of the research is to determine whether or not recent malfunctions in Samsung’s Galaxy Note 7 Smartphone will have a negative impact on consumers’ intention to buy from Samsung’s other product lines. The hypothesis is, as previously stated, that these malfunctions will, indeed, have an impact on individuals’ intention to buy from Samsung.

C. Importance of the Study

This study will obviously be of great importance to Samsung since it is specifically addressing its product and the effects that these malfunctions could be causing for its sales even
when the product being sold is not a smartphone. In short, it will help determine how much damage these smartphone malfunctions have done to Samsung’s overall brand and, consequently, people’s willingness to purchase from them. It’s also true that even though this study concerns a Samsung product, the research done here can be potentially useful to many other companies as well by shedding some light on how easily consumer distrust of one product line can transfer to another.

II. Literature Review

A. Word of Mouth.

Word of Mouth can be considered an oral or written recommendation of a good or service from one customer to another; in this case the product is Samsung. These recommendations, both positive and negative, ultimately have an impact on a consumer’s brand perception as well as a company’s image. While word of mouth is considered to be one of the most effective forms of promotion, it does come with its own set of risks. This is because consumers are free to voice their opinion, and are not limited to only positive reviews. A study on electronic word of mouth conducted by Mohammad Reza Jalilvand and Neda Samiei (2011), supports the idea that there is a correlation between the two variables word of mouth and brand perception. More specifically, Jalilvand and Samiei identified within their study that word of mouth communication had a considerable effect on variables such as brand perception which indirectly affects purchase intention (Jalilvand & Samiei, 2011). Based on the notions proposed in this piece of literature, we propose the following:

Hypothesis (H1): Word of Mouth has a significant effect on brand perception.
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**B. Advertising.**

In the context of this study, advertising is understood as the way the brand and, or product is portrayed in the media. In this day and age, various technological platforms such as social media and television are significant contributors to how the public obtains information. The information provided is not necessarily filtered or monitored and can greatly influence a consumer. Aaker & Biel (1993), supports this notion by stating that a consumer’s perception of quality is often determined by the portrayal of the brand in media as well as the advertising campaigns. When the consumer is exposed to this material, inferences can be made about both the brand and the products associated with it (Aaker & Biel, 1993 p149-150). Based on this literature, the following is hypothesized:

Hypothesis (H2): Advertising has a significant effect on brand perception.

**C. Experience.**

In this study, experience refers to past interactions that consumers have had with Samsung products as well as the Samsung brand in general. Previous experiences whether they may be positive or negative will ultimately illustrate positively or negatively upon the image of a brand (brand perception). This case study focus on the prior experiences with Samsung’s products mainly focusing towards its smartphones. Familiarity and experience especially positive will increase consumers’ perception of a brand, thus increasing the intent to buy.

Authors Park and Stoel spoke about this concept. “. According to the popular press (Brand, 2001), internet shoppers may want to purchase products from websites like these because they recognize the names/brands through experience with other shopping formats” (Park & Stoel, 2005). Based on these pieces of literature, this study proposed the following:
Hypothesis (H3): A consumer’s previous experiences will have a significant effect on their perception of a brand.

D. Perceived Risk

In order to discuss the main issue at hand, first, we need to describe what a ‘perceived risk’ actually means. In layman terms, it can be described as a lack of confidence a buyer has in a product. Clearly, when a consumer buys some product, he/she is extra careful on choosing the brand of the product due to this lack of confidence in the production company. Moreover, this perceived risk is increased for products with a high price in the market. As stated by Mitchell (1992) perceived risk may influence a consumer’s uncertainty in the brand or product. Consequently, this uncertainty will allow a consumer to establish their own preference in the product or brand and ultimately influence the perception of the brand. Furthermore, the study proposes the notion that a consumer will hold more of a preference, and have a higher perception in a brand that has less risk associated with it (Mitchell, 1992). With this in mind, this study proposes the following:

Hypothesis (H4): A consumer’s level of perceived risk will have a significant effect on brand perception.

E. Trust

Brand trust is simply defined as how much a consumer trusts a particular brand. In the case of Samsung, brand trust would mean whether or not a customer believes that Samsung is telling the truth about its products in a given commercial or that Samsung genuinely cares about them and will try its hardest to resolve any issues they run into when using a Samsung product or service. When it comes to how trust impacts brand perception it’s not difficult to see where the two are connected. It’s practically common sense that trust is one of the primary cornerstones if
not the primary cornerstone to any healthy brand image. Research by Mindi Chahal (2013) discusses the impact of trust as it pertains specifically to online experiences but, it’s easy to see how the same rules apply outside of an online setting. Essentially, when brand shows the customer that they can trust it wherever and whenever they interact with it, it contributes to building the overall perception that the consumer will have of that brand going forward; the more a consumer trusts a brand the more positive their perception of that brand will be (Chahal, 2013). For this reason, the study proposes the following:

Hypothesis (H5): Brand trust has a significant effect on brand perception

F. Brand Perception.

In the context of this study, brand perception is understood as the public's view of the brand or company. More specifically, it is the mental image, words, and feeling that the consumer associates with a brand or company. Upamannya, Sankpal, & Gupta (2015) believe this image perceived by the consumer holds a large amount of weight, and can significantly impact a company and its products and services. It is believed by many that this viewpoint on the brand will greatly have an impact on a consumer’s behavior in regards to the brand. According to Esch, Langner, Schmitt, & Geus (2006), the behavior can be understood as a consumer’s current and future purchasing decisions or intention to buy. Given the recent malfunctions of the Samsung Galaxy Note 7 it is believed that the consumer’s perception of the Samsung brand will be impacted. This information coupled with the definition of brand perception suggested by the literature above proposes the following notion:

Hypothesis (H6): Consumer’s brand perception will have a significant effect on a consumer’s intention to buy other products.
III. Methodology

A. Data Collection

In order to collect data that was pertinent to the research topic, a survey was constructed. The survey comprised of questions that fell into two categories: demographic and target. The demographic questions were included to determine the participant’s age, gender, and income. A series of four target questions were devised for each of the seven factors being tested and were compiled into a twenty-eight question survey. The twenty-eight questions were placed in a random order to refrain the participant from predicting which variable was being tested. Each of the participants recorded their responses on the Likert-type scale (1-7) that was assigned to each target question in the survey.

A total of 104 participants took part in the study. The participants were randomly selected from the Manchester, New Hampshire community, primarily on the Southern New Hampshire University campus. As a result, a significant portion of the sample happened to be either students or faculty of the university. The surveys were distributed and taken on an individual basis away from the researcher to maintain accuracy and limit influence. When collecting the data, the surveys were kept anonymous to ensure that only the aggregate data was considered.

B. Data Analysis

1. Cronbach’s Alpha

In order to thoroughly analyze the results of the study, the IBM SPSS data software was utilized. With this software, we were able to run the following: Cronbach’s Alpha, descriptive statistics analysis, and regression analysis. Cronbach’s Alpha allowed us to assess the reliability
of the survey and its overall consistency. The test was conducted on all seven of the factors included in the study, and the results were measured on a scale from 0-1 (University of Virginia Library, 2016). For the purpose of our study, a score that was above a 0.50 was deemed sufficiently reliable.

2. Descriptive Statistics

The IBM SPSS analytical software was then used to obtain a better and more thorough understanding of the sample used for the study. More specifically it allows us to present the information provided in the study in a more meaningful fashion. Ultimately, running a descriptive statistics analysis will identify any patterns in the demographic characteristics in relation to the overall results of the study (Laerd Statistics, 2013).

3. Regression

The third and final step to our analysis was to run the data through regression. Regression analysis is a statistical tool that can be used to test the relationships between variables. More specifically, running a regression analysis will allow us to quantify the effect our independent variables will have on the dependent variables. Ultimately, this method of analysis will determine if there is any “statistical significance” to the relationships hypothesized in this study. For this study, in order for the relationship to be considered “statistically significant”, it had to have a level of significance lower than a 0.05 (Sykes, 1993).

IV. Results

A. Cronbach's Alpha

After conducting the analysis for each of the seven variables, all seven of the variables were deemed reliable, and were assigned a score higher than 0.50. However, in order to obtain such a score, questions associated with certain variables had to be removed from the analysis. A
A QUERY INTO THE POTENTIAL EFFECTS OF SAMSUNG’S RECENT SMARTPHONE MALFUNCTIONS ON THE MARKETABILITY OF OTHER PRODUCT LINES

list of accepted and omitted questions utilized in the study can be seen in Appendix A. and Appendix B respectively. The Word of Mouth variable had two of its four questions omitted and received a reliability score of 0.679. The Advertising variable had no questions omitted, and received a reliability score of 0.639. The Experience variable had one of its four questions omitted, and received a reliability score of 0.764. The Perceived Risk variable had one of its four questions omitted from the study, and received a reliability score of 0.709. The Trust variable had no questions omitted, and received a reliability score of 0.804. The Brand Perception variable had one of its four questions omitted, and received a reliability score of 0.749. Lastly, the Intention to Buy variable had one of its four questions omitted, and received a reliability score of 0.670. A visual representation of these results can be seen in Table 1.1 located in Appendix D.

B. Descriptive Statistics

Running a descriptive statistics analysis allows us to obtain a better visualization of who exactly took part of this research. For this study, there were four demographic factors that were taken into consideration: age, gender, income, and ethnicity. Appendix C. can be referenced for list of all demographic questions and how they were formatted on the survey. Table 2.1 located in Appendix D. provides a visual representation of exactly how many people answered these particular demographic questions. Even though not every participant fully completed the demographic portion of the survey, the information remains valuable. In regards to age, over 74% of the participants fell within the 18-22 age bracket, the millennial generation; with the average age being around 19. The other 26% fell within a wide range of ages from 23-84 years old. A visual representation of these results can be seen in Table 2.2 located in Appendix D. In terms of gender, males had the slight majority comprising of nearly 57% of the sample. The
females counted for the other 43%; a visual representation of these results can be seen in Table 2.3 located in Appendix D. Just over half of the sample (55%) possessed an annual income that was less than $15,000, while 25% of the participants made between $15,001-$45,000. For the other participants, about 5% made between $45,001-$75,000, 1% made between $75,001-$100,000, and about 8% made an average annual income over $100,000. A visual representation of these results can be seen in Table 2.4 located in Appendix D. Lastly, as shown in Table 2.5 Appendix D, a significant portion of the sample identified as Caucasian (70%). For the other ethnicities, African-Americans made up about 4% of the participants, Asian-Americans 3%, and the survey option “other” accounted for 23%. In summary, the study was predominantly taken by Caucasian males, ages 18-22 with an average annual income of less than $15,000.

C. Regression Analysis

As mentioned above, the regression analysis was run to determine the “statistical significance” of the relationship between the variables being tested. For the regression each hypothesis was tested and put through the analysis. Overall, after running the regression, all the relationships were proven to be “statistically significant”, and had a level of significance less than 0.05. Specifically, the hypothesis (H1): Word of Mouth has a significant positive effect on brand perception, was accepted with $\alpha = 0.018$. The hypothesis (H2): Advertising has a significant positive effect on brand perception was accepted with $\alpha = 0.000$. The hypothesis (H3): A consumer’s previous experiences will have a significant positive effect on their perception of a brand was accepted with $\alpha = 0.000$. The hypothesis (H4): A consumer’s level of perceived risk will have a significantly positive effect on brand perception was accepted with $\alpha = 0.000$. The hypothesis (H5): Brand trust has a significantly positive effect on brand perception was accepted with $\alpha = 0.000$. And lastly the hypothesis (H6): Consumer’s brand perception will
have a significantly positive effect on a consumer’s intention to buy other products was also accepted with $\alpha = 0.000$.

V. Discussion

Overall, the results of our research support all of the hypotheses proposed in the study. However, these findings do not necessarily propose any new theories, but rather confirm the previous notions of numerous other researchers. Specifically, it emphasizes the significance of the correlation that exists between the variables being tested. In fact, it is in the significance of these correlations, that we believe the value of our research lies. Based off the relationships that were discovered, such as the correlation between word-of-mouth and brand perception, it is quite plausible that the Samsung Galaxy Note 7’s malfunctions are negatively influencing the sales of other product lines. Given the fact that there has been much negative press on the phone and the fact that individuals hearing negative comments via word-of-mouth also have a more negative perception of the Samsung Brand, this would only seem natural. Furthermore, we predict that the malfunctions of the Samsung Galaxy Note 7 will also have various levels of influence over the variables of, advertising, experience, perceived risk, trust, and ultimately intention to buy as well. Overall, this demonstrates the severity of the impact one negative event can ultimately have on an entire brand. By exploring the situation more in-depth, and quantifying the results we hope to provide big-brand companies like Samsung, as well as the general public a better comprehension of just how fragile brand perception is, and the lasting impact an issue of this nature can have on potential sales.
VI. Conclusion

A. Summary

The case outlines that brand perception is indeed affected negatively or positively by the factors that were studied. Thus brand perception ultimately has an impact on a consumer's intent to buy. Word of mouth, advertising, perceived risk, experience, and trust were the factors used, record, and analyzed to test out this hypothesis. The Method used to collect the necessary data was distributing surveys. Creating questions that were tailored and correlated to each factor, was the first step to proving the hypothesis. Once the data was collected would later be inputted into the IBM software to run the reliability analysis. During the regression portion, we discovered that all the factors indeed had a correlation with brand perception like stated above in the discussion part, the correlation between the factors was negative.

B. Limitations

One of the limitations of the study occurred in the data collection process. During this step, an error was identified in regards to one the questions of the survey. Specifically, the Likert scale on this particular question was not formatted in congruence with the other questions. However, only three of the five researchers were able to spot and correct the issue prior to issuing the surveys. In order to stay within legal parameters and ensure no data was at risk of being fabricated, the data associated with this particular question was ultimately withdrawn from the study.

The amount of demographic questions asked in the survey could be seen as a limitation as well. In this study, only the factors of age, gender, income, and ethnicity were taken into consideration. Other factors such as education and marital status were excluded. Consequently,
adding more demographic questions would create a more informative survey and allow for a deeper analysis of the sample and the results.

Another limitation we were faced with in the study was the occurrence of missing values. As mentioned above, in order to stay within legal parameters and avoid the risk of data fabrication, mean imputation was utilized. This method was used to statistically predict the missing values based on the data that had already been acquired but, it is still constitutes an inaccuracy in the data.

The final limitation was the fact that the sample used in this research was rather homogenous. A vast majority of the students who took the survey fell within the age bracket of 18-22 years of age. It’s also true that, when compared to Samsung’s customer base, Caucasian people are over represented in the sample. Perhaps the largest source of homogeneity, though, is the fact that most of the individuals surveyed are all currently attending the same university and are therefore all share a very similar social atmosphere. Once again, this prevents the sample from being truly representative of Samsung’s customer base or the public as a whole.
References


Appendix A. - Accepted Questions

Word of Mouth:
1. I am afraid to buy a Samsung product because of the things I’ve heard
2. The media has influenced my opinion of Samsung

Advertising:
1. I am very familiar with Samsung’s commercials
2. I know Samsung makes other products besides smartphones
3. I am familiar with Samsung on social media
4. Samsung’s ads have influenced me to buy

Experience:
1. I have had enjoyable experiences with Samsung products
2. Samsung products are easy to use
3. I have had a positive experience with Samsung customer service

Perceived Risk:
1. The thought of purchasing Samsung products will give me a feeling unwanted anxiety
2. Friends and relatives will disapprove Samsung products
3. It is not worth it to put money in Samsung products

Trust:
1. Samsung gives the impression that it keeps its promises and commitments
2. I believe that Samsung has my best interest at heart
3. I trust Samsung to provide me with safe, functional products
4. Samsung’s products are trustworthy

Brand Perception:
1. I prefer Samsung products over Apple products
2. I believe that Samsung makes high quality products
3. I have a positive perception of the Samsung brand

Intention to Buy:
1. I would be willing to buy a Samsung TV
2. I would be willing to buy a Samsung smartphone
3. I would recommend Samsung products to friends and family
Appendix B. - Omitted Questions

Word of Mouth:
1. I have only heard good things about the Samsung brand
2. I have had friends and family members recommend Samsung products

Advertising:
N/A

Experience:
1. I have had difficulty with Samsung products in the past

Perceived Risk:
1. I want to purchase Samsung products because everyone uses them

Trust:
N/A

Brand Perception:
1. Recent events have not changed my perception of the Samsung brand

Intention to Buy:
1. Samsung Galaxy Note 7’s malfunction will not deter me from buying Samsung products in the future
Appendix C. Demographic Questions

Age: Participants wrote in their own age

Income:

1. >$15,000
2. $15,001-$45,000
3. $45,001-$75,000
4. $75,001-$100,000
5. <$100,001+

Male and Female: Participants were asked to circle one

M or F

Ethnicity:

1. African-American
2. Asian-American
3. Caucasian
4. Native American
5. Alaskan Native
6. Hawaiian Native
7. Other Pacific Islander
8. Other
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Appendix D. - Tables

1.1

<table>
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<th>Variable</th>
<th>Trust</th>
<th>Word of Mouth</th>
<th>Perceived Risk</th>
<th>Experience</th>
<th>Advertising &amp; Marketing</th>
<th>Intention to Buy</th>
<th>Brand Image/Perception</th>
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<td>0.749</td>
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2.2

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A QUERY INTO THE POTENTIAL EFFECTS OF SAMSUNG’S RECENT SMARTPHONE MALFUNCTIONS ON THE MARKETABILITY OF OTHER PRODUCT LINES

2.3

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<td>Female</td>
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<td>Male</td>
<td>60</td>
<td>57.3%</td>
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2.4

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<td>1%</td>
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<tr>
<td>Over $100,001</td>
<td>8</td>
<td>7.7%</td>
</tr>
</tbody>
</table>
“A QUERY INTO THE POTENTIAL EFFECTS OF SAMSUNG’S RECENT SMARTPHONE MALFUNCTIONS ON THE MARKETABILITY OF OTHER PRODUCT LINES”

2.5

<table>
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<tr>
<th>Ethnicity</th>
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</tr>
<tr>
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</tr>
<tr>
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<td>23.1%</td>
</tr>
</tbody>
</table>
Explore Marketing Expense in Arts and Cultural Organizations

Hyunjung Lee
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Introduction

In today’s competitive market, Arts and Cultural Organizations (ACOs) face increased direct and indirect competition for resources. To be competitive in the marketplace, ACOs utilize marketing as a major communication tool with their stakeholders, who include donors, ticket buyers, and volunteers. It is a necessity for nonprofit ACOs to acquire financial and non-financial resources to accomplish their societal missions. As a result, marketing strategies in ACOs focus on increasing revenue and cultural participation. Research shows that marketing activities in ACOs have positive effects on their performance.

Recently, many ACOs have reduced marketing activity for fear of public perception on how organizations spend donor’s money while they need to continually engage in marketing activities to attract and retain their donors and ticket buyers. So, questions become (1) How much do ACOs value or emphasize marketing activities in their operation? (2) What factors influence Marketing Emphasis (ME) in ACOs? To the best of our knowledge, no research has investigated the relationship between ME and organizational characteristics in ACOs. This study will fill the research gap by analyzing marketing expense and organizational characteristics in ACOs.

Data and Model

Our data are taken from the Cultural Data Profile (CDP) compiled by DataArt. Thousands of nonprofit ACOs in U.S. use CDP annually to report their financial and programmatic information. The CDP does not include all ACOs in the U.S. and is not a random sample. CDP includes data from ACOs that either participated voluntarily to be a part of the data
collection effort or applied for a grant from a funder that was affiliated with the CDP. The detailed information about the database can be found in the DataArt website (http://culturaldata.org/).

Our sample includes all organizations that participated in CDP in any year during the 2003 and 2013 time period. This data yielded an unbalanced panel of 36,629 observations over the 11-year time period, which includes 8,248 different ACOs. After a data cleaning step, our final data set had an unbalanced panel of 19,730 observations over the 11-year time period, which included 5,106 different organizations. Our data from eight states, Arizona, California, Illinois, Massachusetts, Michigan, Minnesota, New York, Pennsylvania, are analyzed in the study. ACOs in New York, Pennsylvania and California make up 63% of data.

A fixed effect econometric model is used to examine the relationship between ME and organizational characteristics. We measured ME as share of marketing expense in total expense (marketing expense/total expense) and included age, industry, number of board members, share of commercial revenue in total revenue(total commercial revenue/total revenue), share of donation revenue in total revenue (total donation revenue/total revenue), share of government revenue in total revenue (government revenue/total revenue), share of investment revenue in total revenue (total investment revenue/total revenue), debt margin (total liability/total asset), and total margin (total net asset/total revenue). To overcome potential endogeneity, we use lagged values of our independent variables as regressors in our econometric model.

Results

Based on our empirical results, we concluded the following: (1) On average, 8.6% of total expense in ACOs is used for marketing activities and the ratio has been declining since year
of 2008; (2) larger ACOs have higher ME than smaller ACOs; (3) A 10% increase in the share of contribution revenue in total revenue is associated with a 0.28% increase in ME; (4) A 10% increase in the share of commercial revenue in total revenue is associated with a 0.24% increase in ME; (4) A 10% increase in the share of investment revenue in total revenue is associated with a 0.06% increase in ME. Age, industry, share of government revenue in total revenue, financial flexibility (debt margin and total margin), and revenue diversification are not related to ME in ACOs.

Conclusion

ACOs spend 8.6% of their total expense for marketing and the ratio has been declining since 2008. ME in ACOs is determined by the size of an organization and shares of donation, commercial, and investment revenue in total revenue. Among the three shares of revenue, the share of donation revenue in total revenue is most associated with ME, followed by share of commercial revenue in total revenue, and least associated with ME is the share of investment revenue.
Marketing to Women of Color: The Impact of Eurocentric Beauty Standards

This project sought to examine the extent to which white beauty standards are present in advertisements depicting women of color. The methodology involved reviewing advertisements from a sample of back issues from the past five years of three magazines that primarily target a different demographic of women: White, Hispanic, and Black. The advertisements were evaluated by the researchers to determine whether there was evidence of white beauty ideals being imposed on women of color. Advertisements determined by the researchers to do so were subsequently presented to women of color in a focus group to better understand the feelings generated by the ads amongst these young women.
Pandemic diseases message framing: A three country analysis.

Anthony K. Asare, Quinnipiac University
Tilottama Ghosh Chowdhury, Quinnipiac University
Patricia Norberg, Quinnipiac University
Jun Kang, Hunan University China
Richard Bannor, University of Ghana Legon

Researchers have examined effective approaches to health messaging however they tend to examine health messages using diseases and illnesses that, although can be life threatening, are not usually pandemics. The majority of the health messages in the marketing literature are related to life style health issues such as smoking related health issues, heart problems, STDs and obesity. Unlike pandemics, these lifestyle health issues can for the most part be controlled by the patients and as such their response to health messages are expected to be different from their responses to messages related to pandemics, most of which they have no control over. Using 4 experiments, this paper examines the effect of message framing on the effectiveness of health related ads. The experiments are conducted across three countries: Ghana, USA and China and multiple pandemics are examined (including Ebola, Avian Flu and Swine Flu). The paper also investigates the role that cognitive, heuristic and emotional processing play in people’s responses to valence framed health messages. This paper contributes to the literature on health messaging by focusing on messaging in an area (pandemics) that has not been adequately researched. Our research also contributes to practitioners by helping governments, medical health professionals and International Non-Governmental Organizations identify effective messaging approaches to use during pandemics.
The Impact of the SNHU Arena Naming Rights On Student Retention

12-15-2016
SNHU ARENA NAMING RIGHTS

Abstract

Recently, Southern New Hampshire University (SNHU) contracted with SMG to rename its building in downtown Manchester. The new name is “SNHU Arena.” One of the goals of this multi-year partnership between SNHU and SMG is to bring higher education opportunity to Manchester communities.

The overall objective of this research is to examine the impact from this partnership between SNHU and SMG. It is assumed that this new business partnership will increase the visibility of the SNHU brand in the community and in the state. An increase in the brand’s exposure has a positive impact on students’ perception. The name change creates a favorable shift in perception compared to competition. We hypothesize that a change of the name will increase students’ loyalty for use of the SNHU arena. The location of the SNHU Arena will positively impact the brand perception. Consequently, the overall positive impact on brand perception will correlate to higher student retention.

Research questions were designed for a survey based on the variables deemed relevant. Closed-ended questions were issued in the form of a 7-point Likert scale. In other words, the possible answers to the survey questions ranged from strongly disagree to strongly agree. For example, one of the survey statements was, “The name change will give me more opportunities as a student at SNHU.” The survey was administered to 151 participants and their names were kept anonymous. SPSS (a regression analysis tool) was used to analyze the data and reach objective conclusions. The study was conclusive and indicated significant relationships between the variables.
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1. Introduction

This study focuses on the influence arena naming rights have on the retention rates at Southern New Hampshire University (SNHU). The university recently purchased the naming rights to the formerly known Verizon Wireless Arena in Manchester, New Hampshire. The arena is now titled the SNHU Arena. In this study, participants were surveyed using questions that focused on location, exposure, loyalty, competition, brand perception, and retention. The final model looked at how location, loyalty, exposure, and competition of the SNHU Arena influenced brand perception. Then the study looked at how brand perception would effect retention of students at Southern New Hampshire University.

Location was chosen as an independent variable in order to look at the how the location of the SNHU Arena in relation to Southern New Hampshire University would influence students’ use of the space. If students had a positive view towards the location of the SNHU Arena, then their overall brand perception would increase. The nearby location of a stadium leading to positive brand perception was seen in a previous study titled “Green Point Residents’ Perceptions of the 2010 FIFA World Cup: A Post-Event Analysis,” the study found that residents saw the increased economic benefits their local stadium had on the community, which led to a positive overall view of the stadium (Tichaawa & Bama, 2012).

The study also looks at how the SNHU Arena will increase the exposure of the Southern New Hampshire University brand as a whole. When people see that famous performers are coming to the SNHU Arena that will increase the public’s knowledge of Southern New Hampshire University. In the study “Measuring Effects of Naming-Rights Sponsorships on College Football Fans’ Purchasing Intentions,” Terry Eddy found that naming rights partnerships creates a high amount of exposure for the brand that owns naming rights (Eddy, 2014). The
additional promotion of the SNHU name will increase student perceptions of the brand and the university.

This study is investigating if knowledge and use of the SNHU Arena will add to a student’s choice to choose SNHU over a different university. A former study, conducted by Jonathan Jensen, Joe Cobbs, and Brian Turner, looked at whether or not sponsorship would give a company a competitive advantage. Their study looked specifically at the relationship between Visa and the Olympic Games, finding that through sponsorship Visa has created an advantage towards its competitors (Jensen, Cobbs, & Turner, 2016). This study is examining whether or not the SNHU Arena will increase a potential or current student’s perception of SNHU, therefore making SNHU better than another school competitively.

The variable of loyalty looks at whether or not students will choose going to the SNHU Arena rather than another venue because of the name it shares with the students’ university. Loyalty’s influence on brand perception was observed because in the study, “Understanding University Brand Loyalty: The Mediating Role of Attitudes Towards the Department and University,” it was found that the performance of a university has a direct influence on student loyalty (Erdoğmuş & Ergun, 2016). This could also show how the relationship between students and their university can influence whether a student will be more likely to choose items directly associated with their university.

Brand perception is created by a consumer’s experiences. The previously mentioned variables all build upon a student’s knowledge of SNHU and will impact that student’s overall perception of Southern New Hampshire University. A study done by Samar Rahi found that a positive brand perception can be influence by loyalty which will lead to high retention rates for
SNHU ARENA NAMING RIGHTS

the brand (2016). With that being true, then the purchasing of the SNHU Arena naming rights should influence a positive correlation in Southern New Hampshire University’s retention rates.

Lastly, the retention of consumers was looked at in a study by Robert Lindsey, Eugene Sessoms, and Georgia Willis. The three looked at the impact campus sports facilities would have on recruitment and retention among students (Lindsey, Sessoms, & Willis, 2009). This study found that a high percentage of student athletes were influenced to stay by the quality of the athletic facilities. While the SNHU Arena is not a sports arena, it is easily accessible by SNHU students for several different types of events. The perception of the SNHU brand created by the aforementioned variables very well could influence the retention of students at Southern New Hampshire University’s Manchester, New Hampshire campus.

The findings from this study will look at whether or not Southern New Hampshire University’s new sponsorship with the purchase of the SNHU Arena naming rights will influence student retention rates. The purpose of this study will show faculty and staff at Southern New Hampshire University’s Manchester, New Hampshire campus whether or not this sponsorship will positively influence SNHU as a whole. All of the people surveyed are current SNHU students, therefore the perspectives and findings are all based off of actual student opinions. The university can look at this study to see whether or not it will be a wise decision to renew the naming rights contract when it is up for renewal.
SNHU ARENA NAMING RIGHTS

2. Literature Review

2.1 Exposure

Exposure can be defined as the condition of being subject to some effect or influence, public appearance, attention, or discussion. The study is exploring if the gaining of the SNHU Arena has increased exposure of SNHU brand. In this article about brand recognition by Bill Shea, he suggests that brands will see an increase in exposure resulting from gaining naming rights over an arena. When a brand puts its name on an arena, the arena will expect high amounts of media exposure recognizing that brand. “Companies buy arena naming rights for the value of the brand exposure” (Shea, 2016). In a different article, “Measuring Effects of Naming-Rights Sponsorships on College Football Fans’ Purchasing Intentions”, which is about the effects of naming-rights on college football stadiums, the author discusses the recognition benefits for sponsors having their name on a building. “There is a great deal of exposure than can be gained by partnering with college athletic departments” (Eddy, 2014). Having sponsors’ names on an athletic stadium or arena will give more recognition and awareness to that sponsor. In the case of this study, SNHU having its name on the arena will promote the SNHU brand and more people will recognize it and associate that arena with Southern New Hampshire University.

An increase in the brand’s exposure has a positive impact on students’ perception. This hypothesis is important because the way students are exposed to the SNHU brand may impact their perception of the brand. Students may perceive the brand in a more positive way as it is expanding to different areas that it wasn’t in before. People may see the SNHU Arena and associate it with the university, even if they have never heard about it previously. These naming rights put an advertisement out there for the brand to be easily recognized by people who were never exposed to the university before.
The fundamental principle behind location as a variable in this study is centered on the relationship between attractiveness and accessibility (Ghiță, 2014). That is, the consumer’s willingness to transport from his or her original location is influenced by the utility (value) and attraction of the destination. The business’s accessibility can also be a constraint to its attraction if the city’s infrastructure does not allow for ease of use—including parking, traffic flow, and sidewalks. For example, the SNHU arena on 555 Elm Street, Manchester, NH is located roughly 4.5 miles from the main campus at 2500 North River Road, Hooksett, NH. Although it is not directly adjacent to the university, the SNHU arena is in a metropolitan area downtown in New Hampshire’s largest city.

As an independent variable, location is a factor believed to directly influence perception, specifically brand perception. For example, a 2012 study in South Africa showed that events held at a stadium location positively influenced the perceptions of nearby residents when they understood the economic benefits (Tichaawa & Bama, 2012). The same conclusion was reached in a German study which found that the location of a multi-purpose arena improves the desirability and overall perception of the surrounding area (Ahlfeldt & Maennig, 2009). Thus, the hypothesis is that location and brand perception is positively correlated. That is, when the customer believes the location is convenient/accessible and adds value, the brand perception is higher. When the location is not convenient and accessible, the brand perception is low. In the case of the SNHU arena, the previous research conducted suggests that students will believe it to be both attractive and accessible, which will positively benefit the overall perception of the SNHU brand. When students view the location as attractive and accessible, brand perception increases.
2.3 Competition

Competition is striving to outdo another company or organization for supremacy or a prize. That prize being students wanting to attend SNHU and events associated with the SNHU brand. SNHU wants to be the top choice for perspective students as do any other universities. What makes SNHU different is that it is adding an asset to its company that will make it more desirable than its competition. This study focuses on trying to investigate if this asset has a large impact on student’s perception on SNHU and the competition.

In the study being conducted, the popularity of the SNHU Arena for perspective students thinking of attending SNHU is explored. In the article “Evaluating Sponsorship Through the Lens of the Resource-Based View: The Potential for Sustained Competitive Advantage”, the authors examine sponsorship and its potential for a firm to hold a competitive advantage. A study previously mentioned stated, “sponsorship should be viewed as an opportunity to create a competitive advantage for the investing organization” (Jensen, Cobbs, & Turner, 2016). As SNHU adds the naming-rights of the arena to its assets, it opens up the opportunity to gain a competitive advantage over other universities.

The name change creates a favorable shift in perception compared to competition. The gaining of the naming rights over the arena will give SNHU a competitive edge over students thinking about attending the university as well as students attending more events at the arena with the SNHU brand on it. SNHU can use this opportunity to create favorable student perceptions for the SNHU brand and its entities opposed to the competition.
2.4 Loyalty

Loyalty is having a strong feeling or support for a specific entity. In the article, “Understanding University Brand Loyalty: The Mediating Role of Attitudes towards the Department and University,” Erdoğmuşa and Ergunb address brand loyalty in institutions. Gaining the attention of perspective students as well as creating and maintaining loyalty with current students with the possibility of continuing their education in that institution with a graduate program. In this study, consumers’ loyalty to the SNHU brand through the SNHU Arena was tested. The study done by Erdoğmuşa and Ergunb discusses how important brand loyalty is to a company in order to have repeat customers as well as loyal customers using word of mouth to positively promote the institution to other potential customers. In our study we are trying to see if this name change of SNHU will do just that.

A change of the name will increase students’ loyalty for use of the SNHU Arena. This hypothesis believes that students who attend SNHU will be brand loyal to the institution and will have a positive view on the name change. These types of brand loyal customers will attend and promote others to attend events held at the SNHU Arena. Brand loyal customers will be eager to have a new venue to attend events at. The gaining of the naming-rights will expand students’ loyalty to the brand by using the arena more often because the name is now SNHU Arena and it is associated with their university. It will give them a new place to call home just like with many other universities who take great pride in their stadiums. Loyalty will impact the brand perception students have of SNHU.
2.5 Brand Perception

In the framework of our study, brand perception is a variable influenced by all the variables previously listed—competition, exposure, loyalty, and location. According to Samar Rahi (2016), consumers differentiate products based on brand image, and the brand perception is formed in the consumer’s mind from knowledge and experience. Also, the consumer’s perceived value of the brand can be formed from evaluating what is being paid and what is received in return (Rahi, 2016). Therefore, the overall brand perception of SNHU is heavily influenced by the four independent variables of student’s perspective on the SNHU arena name change.

This overall brand perception of SNHU is a factor that can also contribute to student retention, which is the dependent variable in the framework. Samar Rahi’s 2016 study showed that the overall perceived value of a brand and its image is significantly correlated with customer loyalty. For example, if the SNHU Arena name change causes a negative perception of the SNHU brand in the eyes of the students, then they will be less likely to be loyal to the school and retain enrollment in the future. However, if the brand perception is positive, those students will be more likely to stay at SNHU in the future, which will benefit the school’s retention rates. This relationship between brand perception and retention is important because it allows the school to identify the impact of its investments (i.e., the purchase of arena naming rights) compared to the benefits (increased student retention). An increase in the brand perception of the overall value added leads to an increase in student retention.
2.6 Student Retention

The concluding dependent variable in the framework is retention. For this study, the retention variable includes student retention only; that is, the likelihood students will retain their enrollment in SNHU. The framework of this study indicates that changes in brand perception will be positively correlated with student retention. For example, a previous study has shown that the availability of sports and sports facilities at colleges creates an increased value perceived by students (Lindsey, Sessoms, & Willis, 2009). This perception in turn leads to higher retention rates, due to the added value provided to the students at the university (Lindsey, Sessoms, & Willis, 2009). Also, a South African study found that the strongest driver of student enrollment and retention was brand aura, the overall positive and negative perceptions of the brand (Angelopulo, 2013).

Therefore in this case, any changes in a student’s overall perception of the SNHU brand could directly influence similar changes in retention rates. It is important to note that the four independent variables—competition, exposure, loyalty, and location—do not individually influence student retention. Rather, those variables combine to impact the overall brand perception of SNHU, which will in turn impact student retention rates.
3. Methodology

For the purpose of this study, regression analysis was analyzed to explore the data. Regression is used when exploring the relationship between one or more independent variables and the impact that relationship has on a dependent variable (Simonoff, 2016). In this study, the hypotheses involving the independent variables exposure, competition, location, and loyalty, were tested against the independent variable, brand perception. After those hypotheses are tested, brand perception will be tested against the target dependent variable, student retention.

The variables were tested by designing four to five survey questions for each variable. After randomly distributing the survey to 151 SNHU students, the strength of the questions were tested by calculating Chronbach’s Alpha Reliability Scores for each variable using SPSS software. The results of this test determined which questions should be used for regression analysis, and which should be discarded.

After defining the variables and hypotheses, the next step is to test the hypotheses, with the questions deemed usable by the reliability test, to determine if in fact, the relationship between the independent variables and dependent variable is strong. By using SPSS, a statistical software, the variables were tested and multiple linear regression models were calculated. The result of these tests show p-values, or the significance of the variable. Since the findings are being predicated on a 95% confidence interval, if the p-value for a given variable is below .05, then the null hypothesis can be rejected and the alternative hypothesis can be accepted. This means that the relationship between that independent variable and the dependent variable can be predicted with 95% accuracy.
4. Results

4.1 Reliability Scores

<table>
<thead>
<tr>
<th>Alpha Chromatic Reliability Score</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Exposure (EX)</td>
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</tr>
<tr>
<td>Competition (CO)</td>
<td>0.78</td>
</tr>
<tr>
<td>Loyalty (LY)</td>
<td>0.81</td>
</tr>
<tr>
<td>Location (LC)</td>
<td>0.59</td>
</tr>
<tr>
<td>Brand Perception (BP)</td>
<td>0.70</td>
</tr>
<tr>
<td>Retention (RE)</td>
<td>0.83</td>
</tr>
</tbody>
</table>

After putting the data through Cronbach’s Alpha Reliability tests, the reliability scores determined which questions were not strongly correlated with the dependent variable brand perception. For exposure, questions two and five were discarded (survey questions 5 and 22, see Appendices). For competition, questions three and five were discarded (survey questions 7 and 18, see Appendices). For loyalty, no questions were discarded. For location, question two was discarded (survey question 10). For brand perception, no questions were discarded. For retention, questions three and four were discarded (survey questions 26 and 27, see Appendices). The results above indicate the final reliability scores for the questions kept for the regression analysis.

4.2 Demographics

<table>
<thead>
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<th>Gender</th>
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<table>
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<td>CT</td>
<td>11</td>
</tr>
<tr>
<td>VT</td>
<td>6</td>
</tr>
<tr>
<td>ME</td>
<td>5</td>
</tr>
<tr>
<td>Other</td>
<td>16</td>
</tr>
</tbody>
</table>
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For the 151 distributed surveys, every participant did not answer every question, especially for demographics. For the results above, there were more female than male participants (41% males and 59% females). This sample was almost entirely single-dimensional, with nearly 90% of the population being Caucasian. Nearly 75% of the sample included in this study has a hometown in either New Hampshire or Massachusetts.

4.3 Regression Analysis

The first model tested the relationship that the independent variables of Exposure (avgEX), Competition (avgCO), Loyalty (avgLY), and Location (avgLC) have on the dependent variable, Brand Perception. The model looks like:

\[ BP = B_0 + B_1 \text{avgEX} + B_2 \text{avgCO} + B_3 \text{avgLY} + B_4 \text{avgLC} + E \]

<table>
<thead>
<tr>
<th>Linear Regression Test 1</th>
<th>Unstandardized Coefficients</th>
<th>B</th>
<th>Sig.</th>
</tr>
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<tbody>
<tr>
<td>1 (Constant)</td>
<td></td>
<td>2.092</td>
<td>0.000</td>
</tr>
<tr>
<td>avgEX</td>
<td></td>
<td>0.134</td>
<td>0.005</td>
</tr>
<tr>
<td>avgCO</td>
<td></td>
<td>0.236</td>
<td>0.000</td>
</tr>
<tr>
<td>avgLY</td>
<td></td>
<td>0.120</td>
<td>0.075</td>
</tr>
<tr>
<td>avgLC</td>
<td></td>
<td>0.142</td>
<td>0.020</td>
</tr>
</tbody>
</table>

After examining the results of the first linear regression model test, Loyalty has a p-value of 0.075. This is above the .05 threshold, which means the impact loyalty has on brand perception cannot be predicted with 95% confidence. The next step is to remove the variable Loyalty and re-run the test. The new model looks like:

\[ BP = B_0 + B_1 \text{avgEX} + B_2 \text{avgCO} + B_4 \text{avgLC} + E \]

<table>
<thead>
<tr>
<th>Linear Regression Test 2</th>
<th>Unstandardized Coefficients</th>
<th>B</th>
<th>p-value</th>
<th>Std. Error of the Estimate</th>
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</thead>
<tbody>
<tr>
<td>1 (Constant)</td>
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<td>2.217</td>
<td>0.000</td>
<td>0.62445</td>
</tr>
<tr>
<td>avgEX</td>
<td></td>
<td>0.145</td>
<td>0.002</td>
<td></td>
</tr>
<tr>
<td>avgCO</td>
<td></td>
<td>0.314</td>
<td>0.000</td>
<td></td>
</tr>
</tbody>
</table>
This time around, every variable used has a p-value below .05, and therefore can be used to predict its impact on Brand Perception with 95% confidence. The final model for the first model is:

$$BP = 2.217 + 0.145\text{avgEX} + 0.314\text{avgCO} + 0.151\text{avgLC} + 0.62445$$

This means that for every one unit increase in Exposure there is a 0.145 unit increase in Brand Perception. For every one unit increase in Competition there is a 0.314 increase in Brand Perception. For every one unit increase in Location there is a 0.151 increase in Brand Perception. The residual error is 0.62445, and this is significant because it means that when calculating Brand Perception with this model, it is the result will be within 0.62445 units of the actual answer.

The second hypothesis being tested is that the brand perception of SNHU students positively impacts the likeliness of student retention. In this model, Brand Perception is the independent variable being tested against the dependent variable, Retention. The model for this looks like:

$$\text{avgRE} = B_0 + B_1\text{avgBP} + E$$

<table>
<thead>
<tr>
<th>Linear Regression Hypothesis 2 Test 1</th>
<th>Unstandardized Coefficients</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>B</td>
</tr>
<tr>
<td>1 (Constant)</td>
<td>-0.134</td>
</tr>
<tr>
<td>avgBP</td>
<td>0.779</td>
</tr>
</tbody>
</table>

The p-value for Brand Perception is less than the threshold of .05, therefore Brand Perception is a strong predictor of Student Reception. The final model for hypothesis two is:

$$\text{avgRE} = -0.134 + 0.779\text{avgBP} + 1.38496$$
This means that for every one-unit increase in Brand Perception, there is a 0.779 increase in Student Retention. The residual error is 1.38496, which means that when calculating Retention using this model, the answer will fall within 1.38496 units of the actual answer.

After multiple tests, it can be confirmed with 95% confidence that Exposure, Location, and Competition have a positive impact on Brand Perception. It can also be confirmed with 95% confidence that Brand Perception has a positive impact on Student Retention. Both null hypotheses were rejected and both alternative hypotheses were accepted.
5. Discussion

This study was designed to better understand the relationship between the SNHU Arena naming rights and student retention rates. It is important to remember that this analysis worked with two different regression models: The first measured four independent variables (Exposure, Location, Competition, and Loyalty) against a dependent variable (Brand Perception). The second model tested the relationship between the dependent variable Brand Perception against our target variable, Student Retention.

Through SPSS regression tests, the original model was simplified to exclude the independent variable Loyalty. As far as the reliability scores go, the dependent variable with the highest alpha reliability score was Loyalty, which ended up being the least significant variable, and thus, removed from the analysis for the final regression analysis. Its p-value was 0.075, which would still be significant on a 90-point confidence interval, but since the study was based on a 95 point confidence interval, it was deemed to be insignificant. Loyalty was defined as the likeliness of students going to an event at the SNHU Arena over another Arena due to the name change. Even though the reliability scores deemed the answers to loyalty questions were the most correlated, it makes sense that college students wouldn’t care as much about where an event was held, rather what the event was. This analysis was surprising, but still did not impact the final hypothesis testing, since removing this variable made the results stronger.
SNHU ARENA NAMING RIGHTS

6. Conclusion

One of the limitations in this study was the amount of time available to collect the survey results. In the time period we were able to collect a high number of surveys, however if there were no time constraints then even more surveys would have been collected. Another limitation would be that there may be other variables that influence retention rates beyond what was looked at in this study. This study is one of the first of its kind and although it found that purchasing naming rights will have a positive influence on Southern New Hampshire University’s retention rates, it may be different for other universities.

Overall, this study found that a positive brand perception, created by location, competition, and exposure, will positively influence retention rates at Southern New Hampshire University’s Manchester, New Hampshire campus. After surveying 151 students, all of the variables had high reliability scores. However, it was found that only five of the original six variables provided significant results in concluding that the purchase of the naming rights for the SNHU Arena will influence the retention rate of SNHU students in a positive manner. The significance of these results can help with the decision making process in the future when choosing to renew the contract for the arena’s naming rights.
References


Appendices

Distributed Questionnaire

Dear participant,

You are invited to take part in a research study titled “The Impact of the SNHU Arena Naming Rights on Student Retention”

The investigators involved in this study: Daniel Martel, Kyle Hicks, Natasha Peltak, and Catherine Krizar, all residing at 2500 North River Road, Manchester, NH 03106.

The overall objective of this research is to examine the impact from this partnership between SNHU and SMG. It is assumed that this new business partnership will increase the visibility of the SNHU brand in the community and in the state. An increase in the brand’s exposure has a positive impact on students’ perception. The name change creates a favorable shift in perception compared to competition. We hypothesize that a change of the name will increase students’ loyalty for use of the SNHU arena. The location of the SNHU Arena will positively impact the brand perception. Consequently, the overall positive impact on brand perception will correlate to higher student retention.

We are kindly requesting your participation this in this study. Participation in this study is not based on incentive. Feel free to discontinue your participation if you wish to not continue. Upon completion the investigators intend to submit the findings of this study to a conference for presentation.

If you have questions or concerns regarding your rights as a subject in this study, you may contact the Institutional Research Review Board (IRB) via their website at https://my.snhu.edu:8443/Offices/AcademicAffairs/Pages/InstitutionalReviewBoard(IRB).aspx.

You will be given a copy of this form for your records.

I have read the above information, and have received answers to any questions I asked. I consent to take part in the study.

Your Signature: ________________________________ Date: __________

Your Name (Printed): ________________________________

Signature of person obtaining consent: ____________________________ Date: __________

Printed name of person obtaining consent: ____________________________

This consent form will be kept by the researcher for at least three years beyond the end of the study.
<table>
<thead>
<tr>
<th>Statement</th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Somewhat Disagree</th>
<th>Neutral</th>
<th>Somewhat Agree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.) I am aware of the SNHU Arena.</td>
<td>1</td>
<td>2</td>
<td>3</td>
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<tr>
<td>2.) I trust that SNHU consistently works to meet student needs.</td>
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<td>3</td>
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<tr>
<td>3.) The SNHU Arena is easy to get to from campus.</td>
<td>1</td>
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<td>6</td>
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<tr>
<td>4.) The SNHU Arena will make SNHU a more popular choice of college to attend in the area.</td>
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<tr>
<td>5.) People from my hometown know about the SNHU Arena.</td>
<td>1</td>
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<tr>
<td>6.) I am more likely to attend events at the SNHU Arena because of the name change.</td>
<td>1</td>
<td>2</td>
<td>3</td>
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<tr>
<td>7.) When applying to schools, SNHU was one of my top three choices of schools in New England.</td>
<td>1</td>
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<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>8.) I am excited about the name change.</td>
<td>1</td>
<td>2</td>
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<tr>
<td>9.) I will be more likely to use the SNHU Arena than other arenas due to the name.</td>
<td>1</td>
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<td>3</td>
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<tr>
<td>10.) I wish the SNHU Arena was closer to campus.</td>
<td>1</td>
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</tr>
<tr>
<td>11.) I support the naming of the SNHU Arena.</td>
<td>1</td>
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<td>4</td>
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<td>6</td>
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</tr>
<tr>
<td>12.) I will recommend the use of the SNHU Arena to family and friends.</td>
<td>1</td>
<td>2</td>
<td>3</td>
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<td>7</td>
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<tr>
<td></td>
<td>Strongly Disagree</td>
<td>Disagree</td>
<td>Somewhat Disagree</td>
<td>Neutral</td>
<td>Somewhat Agree</td>
<td>Agree</td>
<td>Strongly Agree</td>
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<tr>
<td>13.) SNHU seems to improve in some way every year.</td>
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<tr>
<td>14.) This deal will increase the amount of financial aid students are offered.</td>
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</tr>
<tr>
<td>15.) The gaining of the SNHU Arena increases the awareness of SNHU nationally.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
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<td>6</td>
<td>7</td>
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<tr>
<td>16.) SNHU has a competitive edge over other universities now that it owns naming rights for the SNHU Arena.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
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<td>7</td>
</tr>
<tr>
<td>17.) The gaining of the SNHU Arena increases the awareness of SNHU in New England.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>18.) When applying to colleges, SNHU was my number one choice of school in New England.</td>
<td>1</td>
<td>2</td>
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</tr>
<tr>
<td>19.) The change will give me more opportunities as a student at SNHU.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
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</tr>
<tr>
<td>20.) I like that the SNHU Arena is located in downtown Manchester, NH.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>21.) When popular events are held at the SNHU Arena, I’m happy that there isn’t increased traffic on campus.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>22.) I’ve seen advertisements for the SNHU Arena.</td>
<td>1</td>
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<td>7</td>
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</tbody>
</table>
## SNHU Arena Naming Rights

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Somewhat Disagree</th>
<th>Neutral</th>
<th>Somewhat Agree</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>23.) The deal will make SNHU a more prominent name in the Manchester community.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>24.) The SNHU Arena gives me more reasoning to want to stay enrolled at SNHU.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>25.) The increased awareness of SNHU, as a result of the SNHU Arena, increases my likeliness to stay at SNHU.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
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</tr>
<tr>
<td>26.) I look forward to seeing how SNHU utilizes this deal to increase student opportunities in upcoming semesters.</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
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<td>7</td>
</tr>
<tr>
<td>27.) I will continue to utilize the SNHU Arena after graduating.</td>
<td>1</td>
<td>2</td>
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<td>6</td>
<td>7</td>
</tr>
</tbody>
</table>
Demographic Questions: These Questions are used for classification purposes

1. Gender: Female    Male

2. Which among these categories best describe your racial affiliation?
   - Caucasian
   - American Indian or Alaskan Native
   - Hispanic
   - Not applicable (I do not affiliate/identify with a racial group)
   - African, African-American
   - Asian
   - Other

3. Please indicate your Hometown:_______________ State:_______

4. Please Indicate your annual income (Household income)
   - <$20,000
   - $20,001-$40,000
   - $40,001-$60,000
   - $60,001-$80,000
   - $80,001-$100,000
   - >$100,000

5. Please indicate your highest level of education completed?
   - Less than High School
   - High School/ GED
   - Some College
   - 2 Year College Degree (Associates)
   - 4 Year College Degree (B.A. / B.S.)
   - Master’s Degree
   - Doctoral Degree
   - Professional Degree (M.D. / J.D.)

6. Please indicate your age:_______
Using Social Media in the Classroom Workshop

This workshop will introduce the use of social media in the classroom. It will focus on the use of Facebook in particular, but other available platforms such as Twitter, Pinterest and Instagram will be discussed. The interaction functionality of these platforms provides faculty and students with a venue to share ideas, converse about course topics and allows students to dialogue with one another by posting, sharing and collaborating. Rather than being passive receivers of transmitted knowledge, students can be active participants in the learning process. Learning is all about communication. Social media can be used as a teaching tool, as well as a means of communication.

Participants will learn how to introduce social media into their classroom and how to engage students in the learning process. You will learn how to set up your Facebook group for classroom use and how you can get your students involved and excited about participating. Discussions will focus on how to establish the privacy setting of your account so the only participants/viewers of your site are your students and you. You will learn the various tools that are available for use with in the Facebook platform, including analytics. You will be provided sample postings that will elicit class discussion and student participation.

Aside from personal and educational use, social media is very prevalent in the professional work environment. When students enter the work force, they need to be prepared to communicate in a professional manner using social media. By incorporating the use of social media into the course curriculum, students will learn how to engage with others online in a professional manner. This can be challenging if they have not had the opportunity to hone their online communication skills within a professional atmosphere. By using social media as a learning tool, students become more comfortable with the medium and are able to use the various interactive platforms as a productive work tool.
When it Comes to Fashion, is Fake the New Black?

Dr. Heather Kirkwood, Assistant Professor of Marketing, State University of New York-Farmingdale
Dr. Thomas Tanner, Assistant Professor of Marketing, Bloomsburg University of Pennsylvania

Abstract

To gain awareness of the growing implications of counterfeit trade, one needs to look no further than current global news headlines. Stories of seizures of counterfeit food, pharmaceuticals, clothing, accessories, toys, mechanical parts, and other items are astonishingly present on a near-daily basis. As of 2015, the most commonly “faked” items seized in the United States are fashion products: apparel and accessories (Frolich, 2016). From the not-so-secret counterfeit luxury fashion items readily available on the streets of New York City to the multitude of counterfeit items available with the touch of a keyboard at major web retailers like Amazon, eBay and Alibaba, purchasing a counterfeit product is easier than ever. The Counterfeit Report (2017) states that the websites with the most number of consumer complaints about fakes are: eBay, Amazon, Facebook and Alibaba.

Counterfeit products have been in existence for thousands of years; however technological advances have increased their availability and furthermore likely increased consumer propensity to purchase, given the degree of anonymity involved in the online purchase process. Given their illicit nature, only estimates can be made regarding the value of counterfeit products seized at our borders. The Department of Homeland Security reports $1.25 billion of merchandise seized at US Borders in the 2012 fiscal year (IACC, 2013). These numbers are only projected to increase. Counterfeits are a problem with no apparent and effective solution.
Frustrated practitioners and unsuspecting consumers seek resolution, but what can be done about this growing epidemic?

Lambkin and Tyndall (2009) offer that one of the most effective preventative measures a firm can use is to build and maintain a strong brand that will discourage consumers from seeking cheaper, alternative fake versions. Education of consumers, employees and the general public can also be an effective tool. Several trade associations and coalitions have developed YouTube and social media campaigns to reach consumers and educate them about the dangerous implications of purchasing fakes. In addition, while not originally designed for anti-counterfeiting purposes, sophisticated technology such as RFID (radio frequency identification) tag technology has proven to be one effective method for firms to counter such activities.

With the ever-growing number of economic, political and social consequences that arise from counterfeiting, and thus the many implications for marketing, more research is needed in the area of counterfeits. The main purpose of this conceptual paper is to explore consumer behavior toward purchasing non-deceptive counterfeit fashion products in an online context. The authors propose a qualitative study, utilizing individual interviews to determine non-financial motivations for engaging in such behavior. Building on their prior study, the authors examine the following constructs in relation to consumer attitudes toward counterfeits: information susceptibility, normative susceptibility, value consciousness, materialism, integrity, self-identity, and perceived risk.

This study will provide further insights into the determinants of what factors influence consumers to purchase counterfeit goods in the online environment. The study will also contribute to the growing body of literature surrounding counterfeit marketing by constructing a profile of the online purchaser of counterfeit goods; as well assist with the design of effective
anti-counterfeit consumption strategies. Given the overwhelming growth in the consumption of counterfeit goods, the proposed study and its findings are expected to benefit multiple stakeholders: practitioners, academicians, and ultimately consumers. Deeper understanding of consumer attitudes and purchase intentions toward such products can assist with the development of anti-counterfeit consumption strategies.

References


Penz, E and Stöttinger, B (2005), “Forget the “Real” Thing-Take The Copy! An


Abstract:

In this paper, we develop a game theory model in which freight service providers seek to maximize their expected utility by competing with one another for business from shippers and also investing in security. The focus is on high-value cargo, which has been the target of attacks globally, from luxury items of clothing and jewelry to food and high tech products. Shippers reflect their preferences for freight service providers through the prices they are willing to pay which depend on quantities shipped and security levels invested in. The Nash Equilibrium is formulated as a variational inequality problem for which existence is guaranteed. The numerical examples illustrate the methodological and computational framework and reveal impacts of the addition of freight service providers, demand destination nodes, and shippers.
Airtanker Interdiction of Wildfires
An Integer Programming Approach to Optimizing Airdrop Efficiency

Christine Krueger and Emanuel Melachrinoudis
Northeastern University
Department of Mechanical and Industrial Engineering
Boston, MA, USA
Abstract— The natural phenomenon of wildfires threatens thousands of lives and wreaks havoc on millions of acres across the United States every year. The devastation taxes many communities through both the damages done as well as the cost of resources required to minimize them. Highly skilled individuals lead the charge against this threat and are assisted by aerial assets that include airtankers and helicopters. The actual application of these resources is left up to the judgement of the aviation managers, the observations of the smoke jumpers on the ground and the experience of the pilots. This paper applies integer programming to integrate the research done with regard to airtanker airdrop patterns and determine the most efficient utilization of various airtankers and helicopters to achieve containment. The mathematical model was validated using data of an actual fire. Ultimately, this paper seeks to provide decision makers with new and more efficient tools to understand how to best utilize resources and help in the acquisition process.

Keywords—airtankers, wildfires, airdrop patterns, integer programming

I. INTRODUCTION

In 1910, data collection on the effects of wildfires began, and since then 1,086 lives have been claimed and thousands more injured, according to National Interagency Fire Center (2016). Most recently, in 2015, the Insurance Information Institute reported that 68,151 wildfires burned over 10 million acres in the United States and Puerto Rico. Fighting these fires is a joint effort between state and local authorities who employ a large variety of assets to protect the communities threatened. The goal is often to efficiently encircle the fire by a firebreak line, a strip that is cleared of combustible materials or wetted by water or retardant that will make combustion unlikely and thus contain the fire. The resources used to construct the firebreak range from ground assets such as smoke jumpers and bulldozers, to aerial ones like spotters and airtankers. Of particular interest is the capabilities of airtankers to contribute to the containment of the fire especially in terrain that is prohibitively difficult for ground crews to reach. Beyond delivering resupply and personnel to areas that cannot be accessed via ground vehicle, airtankers can deliver thousands of gallons of water, suppressant or retardant rapidly and effectively. In this paper, a model is developed for the efficient firebreak...
development with airtankers by dropping water or retardant to contain a wildfire under time constraints. Relevant data of a 2007 wildfire in California are used to validate the model.

II. OBJECTIVE

A. Motivation

While airtankers have been in use for dozens of years, there is little standardization in the tactics used for their employment. Rather, the experience of flight crews and asset managers is relied upon to determine when and where to apply their efforts. There is little doubt that over the years the application of airtankers has protected many communities and saved countless lives. However, without a standardized practice for the application of airtankers within the overall firefighting picture, there is no way to guarantee they are being utilized to their utmost efficiency. While there is data on different parameters of airtanker use, synthesizing it for practical application requires further exploration. Relying on institutional knowledge provides a moderate amount of success but does not guarantee best practices are shared nationwide and provides very little hard data to be used in the procurement process when decisions need to be made for future capabilities.

B. Goals

This project seeks to provide decision makers with the tools to not only combat actively burning fires but also to provide metrics to inform those involved in acquisitions, so they can understand which resources need to be added to their fleet. Utilizing integer programming, a model is developed which demonstrates the most efficient application of resources. Manipulating the inputs to the model also illustrates the strengths and weaknesses of various aerial platforms.

III. LITERATURE REVIEW

On the whole, wildfires and the fight to contain them is an extremely complicated and intricate problem. Before a fire even begins, individuals across the country have combed through data and weather reports to try to predict the
next fire so that resources can be prepositioned and ready at a moment’s notice. Then, once a fire has ignited, attempting to model its behavior is of vital importance to ensure evacuations are carried out in a timely manner and that the resources are dispatched appropriately. Based on this complexity there is a growing field of research into many aspects of wildfire containment.

First, as this project addresses the use of airtankers in building firebreaks, the Fire Technology Transfer Note provided a basic understanding of the characteristics of retardant and its effectiveness against a fire (see Robertson 1998). However, this discussion was limited to the retardant itself and did not address delivery systems extensively.

A few journal articles applied operations research techniques to the daily deployment of airtankers. First, Islam et al. (2009) used queuing theory in their article “A Time Dependent Spatial Queuing Model for the Daily Deployment of Airtankers for Forest Fire Control.” They argued that the most appropriate model was a M/M/s queue with airtankers being the servers and the fires the customers. Their endstate was to make a user friendly “spatial deployment heuristic” to provide decision makers assistance in locating staging areas for the airtankers. This work only addressed the dispatch of airtankers on a prepositioning and planning level, not at the tactical level.

Similarly, the work of Ntaimo et al. (2012) used stochastic programming to address resource staging. In their work, Ntaimo et al. developed a standard response model (SRM) which helps decision makers through a two stage decision process. The first stage helps determine where to stage the resources for the fire season, then on a given day, the second stage determines the number of resources to be dispatched to a particular fire. The limitation of this work was that it focused only on dozers and did not address aviation assets.

A work which addresses the daily deployment of aviation assets is by Peter Kourtz (1988). While this work addresses the dispatching of aircraft to specific fires, the number of aircraft each fire needed was simply chosen by the manager and the method to determine this was not included in the model. Thus, the objective was to minimize cost as long as each fire received the number of aircraft the manager deemed necessary.

Donovan and Rideout (2003) used integer programming to minimize the cost of containing a fire. Their model was built as a knapsack problem with an added time dimension to it to allow resources to be reused in the next time period. Their focus, similar to Ntaimo et al., was also on ground crews only.
Beyond the optimization models for planning wildfire containment, other works have been published that describe the characteristics of airtankers and their effective deployment. Lovellete (2000) reported on the results of experiments conducted by the USDA Forest Service to determine the dimensions of airdrops by various airtankers and helitankers. Building upon this, Legendre et al. (2013) generalized the results and developed equations so that the tests for future aircraft would not have to be replicated for new aircraft. Simply knowing certain parameters of the aircraft would facilitate calculations of the dimensions of their airdrop.

Additionally, many agencies worked together to share their techniques and knowledge gained. For example, Australia, France, Canada and the United States collaborated on a document of best aerial firefighting practices, which explored each country’s approach to utilizing their aviation assets (see Australian Fire Authority, 2006). It reported on their current fleet composition and made suggestions for future aircraft purchases. This work is similar to the “Large Airtanker Modernization Strategy” of the USDA Forest Service (2012). Both of these works attempted to analyze the efficiency of airtankers on a large scale.

The organization of the remainder of this paper begins with the mathematical model and its application to the California wildfire which is described in Section IV. Section V elaborates on the model results on that particular fire. Finally, the paper ends with the conclusion and future work in Section VI.

IV. METHODOLOGY

A. Formulation

The problem is defined as: given a fleet of aircraft that are available for fire containment operations and a fire threatening a community, build a firebreak line as efficiently as possible. The objective is to minimize the cost of developing the firebreak while constructing it before the fire reaches the community and within the utilization limits of the aircraft. The firebreak line is assumed to have been specified by ground fire emergency services and it is composed of several homogeneous sections, each one having uniform fuel and terrain characteristics, thus requiring a particular coverage level by water or retardant.

This problem definition easily fits within the framework of an integer programming model and is formulated as follows:
Indices:
i = aircraft index
j = airfield index
k = firebreak section index
l = refill point index

Section of Firebreak Data:

$f_k$ = center of section $k$ of the firebreak
$L_k$ = length of section $k$ of the firebreak
$CL_k$ = coverage level required by section $k$ of the firebreak in gallons per hundred square feet

Airfield/Refuel Location Data:

$a_j$ = center of airfield $j$

Refill Point Data:

$r_l$ = center of refill point $l$

Aircraft Data:

$b_i$ = cost to operate aircraft $i$ per minute
$o_i$ = airdrop overlap required for airdrop by aircraft $i$ (a percentage of overlap of overall length of airdrop by aircraft $i$)
$l_i$ = length of airdrop by aircraft $i$ in feet
$v_i$ = airspeed of aircraft $i$ in feet per minute
$w_i$ = time to refill aircraft $i$
$e_i$ = fuel endurance for aircraft $i$ expressed as flying time between consecutive fueling stops
$g_i$ = time to refuel aircraft $i$ in minutes
$F_i$ = maximum allowed utilization of aircraft $i$ in minutes
$cl_i$ = coverage level of aircraft $i$ in gallons per hundred square feet

Other Data:

$T$ = elapsed time the fire will reach particular line analyzed
$d_{lk}$ = distance from center of section $k$ of the firebreak to center of refill point $l$ in feet
$d_{kj}$ = distance from center of section $k$ of the firebreak to center of airfield $j$ in feet
$d_{jl}$ = distance from center of airfield $j$ to center of refill point $l$ in feet
$t_{ijkl}$ = total operating time of aircraft $i$ per airdrop for a given combination $(j, k, l)$ in minutes

$$t_{ijkl} = \left(\frac{2d_{lk}}{v_i} + w_i\right) \left[1 + \frac{\frac{d_{jl}}{v_i} + g_i}{e_i - \frac{d_{jl}}{v_i}}\right]$$  \hspace{1cm} (1)

$c_{ijkl}$ = flying cost of aircraft $i$ per airdrop for a given combination $(j, k, l)$ in dollars per minute

$$c_{ijkl} = b_i t_{ijkl}$$  \hspace{1cm} (2)
\( h_{ik} \) = effective length of airdrop \( i \) on firebreak section \( k \) in feet

\[
h_{ik} = o_i l_i \text{ (given } cl_i = CL_k) \tag{3}\]

Variables:

\( x_{ijkl} \) = total number of trips by aircraft \( i \) to section \( k \) of the firebreak

\[
\text{MIN } \sum_{i,j,k,l} c_{ijkl} x_{ijkl} \tag{4}
\]

subject to:

\[
\sum_{j,k,l} t_{ijkl} x_{ijkl} \leq \min(T_i, F_i) \quad \forall i \tag{5}
\]

\[
\sum_{i,j,k,l} h_{ik} x_{ijkl} \geq L_k \quad \forall k \tag{6}
\]

\( x_{ijkl} \geq 0 \quad \text{and integer} \tag{7} \]

The objective function (4) minimizes total cost of aircraft to build the firebreak. Constraint (5) ensures that the firebreak is built before the fire reaches it or the utilization time of the aircraft is expired. Constraint (6) states that the cumulative length of all the airdrops on a firebreak section is at least as long as the length of that section. Finally, constraint (7) stipulates that the decision variables are non-negative integers. In addition, there are a few parameter calculations in the “Other Data” subsection. The time each airdrop takes (1) is a function of the airspeed of the aircraft, its fuel endurance, refuel time, refill time, and distances between relevant locations. While the plane will not need to refuel on each trip, a portion of the refueling time is allotted into each trip. Next, the cost per airdrop (2) is its operating cost rate multiplied by time. Finally, the effective length of the airdrop (3) is the length of the airdrop per aircraft penalized by \( o_i \) (in this case ten percent) since the ends of the airdrop rarely has the appropriate coverage level. Overlapping airdrops is a common practice in the industry known as anchoring. A ten percent overlap or anchor was decided upon after viewing the results of airdrop pattern experiments. Figure 1 shows an example of airdrop tests conducted by the United States Forest Service (Legendre et al., 2013). The concentric lines show that the closer to
the center, the higher the average coverage level. Conversely, the outside rings are often less than the intended concentration.

![Image](image_url)

**Figure 1: Sample results from airdrop pattern testing**

The coverage level is the industry standard of measuring the amount of water or retardant needed, depending on the type of fuel burning, measured in gallons per 100 square feet or “gpc”. Almost all modern airtankers and even the newest Bambi buckets, the buckets of water slung under helicopters, now have the ability to adjust the rate at which they dispense their load. This allowed for the simplifying assumption that the aircraft in the study could meet the coverage level demanded, but is mentioned to allow for future work if the aircraft available cannot meet the minimum required. Additionally, the coverage level chosen had an effect on the length of the airdrop.

Some of the aircraft considered in this study had conducted airdrop pattern analysis, but to be consistent, an equation from the work of Legendre et al. (2013) was used, where airdrop length is a function of parameters of the aircraft such as tank capacity, width of the door through which the payload exits, airspeed, flow rate and height at which it airdrops. This equation was developed from observing the results of dozens of tests and allowed for the aircraft with no tests to have a length of airdrop calculated. Essentially, the length of the airdrop is a function of the time the aircraft spends airdropping (E), and the airspeed (U), plus the width of the airdrop (λ, from experimental data), times a constant which factors in wind speed (taken as 2 in our case).

\[ l_i \approx UE + 2\lambda \]  

(8)

**B. Application**

To collect a useable data set for this formulation, a meaningful set of fixed wing and helicopter platforms was chosen from a wide variety of aircraft available for combatting wildfires. In order to limit the amount of data required
as well as to ensure the model could solve a relevant problem, the scope of this problem was limited to the resources available to the agencies in Southern California in 2007.

Southern California in 2007 was chosen for its preponderance of data. In October of that year, one of the worst seasons of wildfires struck the southern half of the state. More than a dozen fires ravaged the landscape killing and injuring dozens and causing millions of dollars in damage. Because of its magnitude, very thorough records and accounts have been publicized to include the strategy and resources used to fight the fire. At the time, California, specifically Los Angeles County, used four types of aerial assets, the Canadair 415 “SuperScooper,” the Sikorsky S70 “Firehawk,” the Bell 412 and the Bell 406b. Thus, these were the specific aircraft chosen for the model. Their parameters were gathered from various sources and their airdrop lengths were calculated from the previously mentioned equation (8).

In addition, the different fires from October 2007 were considered to determine which one could provide some of the other data and parameters needed for the model to once again provide realism. The Buckweed fire (shown in Figure 2) was selected for its size, duration, and proximity to a large population, Santa Clarita.

Using the actual progression of the fire, a firebreak was simulated, as shown in Figure 3, to protect the town and then divided into seven homogeneous sections. The terrain and fuel for the fire over this firebreak was all similar but the model is built to accept different types of fuels and terrains. If a firebreak has different fuels and terrain, where
those change would be the delineations in the sections. Locations of airfields and possible refill points were taken from the records as well as inspection of the map.

![Figure 3: Sections of selected firebreak](image)

The model was solved by the modeling language optimization software LINGO. Parameters such as time and cost per airdrop were calculated in MATLAB, and then imported into LINGO. Similarly, the effective length of the airdrop was externally calculated since LINGO could not process those calculations.

V. RESULTS

Implementing this model for the conditions of the Buckweed fire resulted in over 250 integer variables due to the seven sections of firebreak, three airfields, two refill points and up to seven aircraft. The industrial LINGO package was able to solve the model to optimality with various levels of inputs very quickly. When given eight hours, a regulatory limit to a day’s utilization of an aircrew, the model was able to complete the firebreak with only one aircraft, the CL415 “SuperScooper.” Figure 4 below depicts the number of airdrops (left axis) required on each section (bottom axis). The width of the column is scaled to represent the relative length of the section, which demonstrates the predictable fact that longer sections require more airdrops.

![Figure 4: Trial Given 8 Hours](image)
After this result, the actual conditions of the fire were considered. In October 2007, this fire was reported shortly after noon, so the model was run with the time between the discovery of the fire until sunset, when aviation operations have to cease. This gave the model five hours to complete the break which it was able to accomplish but it required additional aircraft other than just the CL415 (indicated by blue in the graphs). It also used the Sikorsky S70 (yellow) and the Bell 412 (green). The airdrops are depicted in a Figure 5.

![Figure 5: Trial Given 5 Hours](image)

To ensure this was a feasible solution to constructing the firebreak, a schedule of sequencing the aircraft to the sections was compiled verifying that these airdrops could be made without two aircraft occupying the same section simultaneously. An improvised heuristic of most airdrops by aircraft per section was employed, a “longest processing time first.” For example, the airdrops of the Sikorsky on section 1, the Bell 412 on section 7 and the Canadair on section 2 were the first to be scheduled. The resulting sequencing shown below in Figure 6 demonstrates that the aircraft can feasibly be sequenced within 5 hours.

![Figure 6: Aircraft Sequencing](image)

To further understand the output of the model, the cost efficiency of the aircraft was calculated. For trial 1, the CL 415 airdropped over 68,000 gallons to create the firebreak at the cost of 33.6 cents per gallon airdropped (cost does
not account for cost of chemicals to create retardant, only operating cost). For trial 2, the total cost per gallon was 69 cents. However, what was more interesting was the difference between the aircraft. The CL415 averaged 33 cents per gallon, while the S70 cost $1.32 and the Bell 412 cost $1.62.

VI. CONCLUSION AND FUTURE WORK

While there is much potential work to be done in this field and on this model in particular, a few observations can be recorded. First, the model can reach an optimal solution that attempts to minimize the cost while building a firebreak in between the origination of the fire and a community. As expected, it selects the most efficient aircraft. However, when using multiple aircraft to meet the time demand, it does not always prioritize sending each aircraft to the section it operates most efficiently in since it is more concerned with the overall result. An additional observation is that this model used less than half the gallons of airdrops than was actually used in 2007. While there cannot be a direct comparison since the location of their airdrops and length are not published, it does suggest that this model could influence the effectiveness and expediency of airtanker use.

This paper provided some insights into the use and effectiveness of airtankers in containing wildfires by building a firebreak line. Even so, the usefulness of this model can be improved. Currently, there are multiple decision making tools used by those who manage the fight to stop wildfires. A popular tool is the Wildland Fire Decision Support System which assists managers to calculate potential damage as well as probable spread of the wildfire if no action is taken and accounting for weather forecasts. Incorporating a model similar to this could help these managers decide where to send available aviation assets. If the manager decides where the firebreak needs to be, the system could generate the assignment of airdrops per aircraft to firebreak sections.

Additionally, in the literature review, some documents were discussed which attempted to inform procurement decisions on which aircraft should be bought for different agencies and countries (Australian Fire Authority, 2006). Inputting the characteristics of these potential aircraft into the model and evaluating the results could assist in this decision making process.
REFERENCES

AN EOQ MODEL WITH NONLINEAR HOLDING COST AND IMPERFECT QUALITY SUBJECT TO DISTINCT DEMANDS FOR CONFORMING AND NON-CONFORMING ITEMS

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ABSTRACT

This paper generalizes the results of an EOQ model with imperfect quality subject to distinct demands for conforming and non-conforming items to the case where holding cost is a nonlinear function of the amount of time an item is held in inventory. As in the previous work, we assume that the vendor operates a process that is in statistical control and ships on a lot-for-lot basis to the purchaser. Purchaser applies a 100% quality inspection policy. It is further assumed that the purchaser’s inspection process is precise and all conforming items are accepted to satisfy demand in a primary market and all non-conforming items are rejected and sent to a warehouse to satisfy demand in a secondary market for non-conforming items. Inspection cost per lot is a linear function of lot size. Shortage costs for the conforming units are assumed to be high. Hence, shortages are not allowed for conforming parts in the primary market while permitted for non-conforming parts in the secondary market. Non-conforming shortage costs are levied based on the number of units short, irrespective of the duration of shortage. All non-conforming leftover units at the end of each cycle, if any, are sold (or disposed of) for a fixed price (or disposal cost) per non-conforming unit. For the scenario described above, along with the notion that holding cost ensues a relationship that is nonlinear in time, the present research cultivates the underlying conditions leading to shortages or excess units of non-conforming items. The paper also develops explicit expressions for the optimal lot size and optimal total inventory cost incurred by the purchaser in both markets for two separate cases of shortages or excess units of non-conforming items. It will be shown that the more general explicit relationships of this paper will reduce to the corresponding results of the previous research based on the assumption that stock can be stored indefinitely to meet future demand.

Keywords: Inventory Theory, Nonlinear Holding Cost, Imperfect Quality
1. INTRODUCTION

The seminal Economic Order Quantity (EOQ) formula, also known as Wilson’s Square Root Formula [1], is the earliest scientific paradigm developed in the early 20th century to aid companies in their inventory replenishment decisions. The square root EOQ relationship is the outcome of customary optimization of total relevant inventory costs under a series of highly restrictive and exceedingly simplifying assumptions including deterministic demand, constant lead time, constant holding costs across time, and perfect quality of replenishment items. However, despite its intense simplicity, the EOQ model is still commonly used in industry today [2].

For the purpose of the present research, let us examine the assumption of constant holding cost. This assumption presumes that stock can be stored indefinitely to meet future demand. While this is true for many items, certain types of inventories can undergo changes in composition, potency, etc. which make them unfit for consumption. To account for these and other issues, researchers have developed a group of inventory paradigms that consider holding cost as a function of the amount of time that an item is held in inventory. Such models are generally studied under the class of perishable inventory models.

Nahmias [9] presents a review of the early work in the area of perishable inventory research. He classifies perishable inventory models into two classes: fixed lifetime and random lifetime. The fixed classification includes those cases where the lifetime is known a priori to be a specified length of time or number of periods. Of greater interest to the current research is the random lifetime classification which includes those cases where the product lifetime is a random variable with a specified probability distribution. A special case in this classification is the case where the lifetime of the product reveals exponential decay. Nahmias [9] reviews the work of a number of authors who have assumed deterministic demand along with exponential decay of items. For these cases the solution of an ordinary differential equation results in a relationship for inventory position over time which in turn is used to determine the optimal order quantity and optimal total cost. The case of stochastic demand presents a more difficult problem. In general, exponential decay problems with random demand are analytically challenging and enormously difficult to solve, especially when replenishment lead-time is a random variable.

Weiss [14] considers a product facing a constant demand rate, constant replenishment lead-time, a fixed ordering cost, and holding cost that exhibits a relationship that is nonlinear in time. Specifically, the unit holding cost follows an increasing function of time, \( t \), and is given by \( H(t) = C_h t^\gamma \), where \( C_h \) and \( \gamma \geq 1 \) are constants. The author develops an Economic Order Quantity (EOQ) model that minimizes average combined ordering and holding costs over an infinite horizon. Ferguson et al [7] develops an approximation of the optimal order quantity for perishable goods such as produce and dairy products sold in small supermarkets that do not receive daily deliveries. The authors apply the Weiss’ model to data obtained from a national U.S. grocery chain. Using regression these data are fit to the nonlinear holding cost model. A series of numerical experiments are performed to test the performance of the model against the classical EOQ. The results of the study show Weiss’ model delivers superior results under a series of robust scenarios. The improvement over the classical EOQ model is more significant for higher daily demand rate, lower holding cost, shorter lifetime, and a markdown policy with steeper discounts.
The EOQ Models with time-dependent holding cost, such as the one developed by Weiss [14] and applied by Ferguson et al. [7], implicitly assume that all items in a lot are of perfect quality. However, due to damages caused during transportation and/or deterioration of the production process or other factors, in real situations, the perfect quality assumption of these models is highly questionable. For these reasons, in the past several years, many researchers have advanced the development of more realistic models that allow for imperfect quality of ordered or manufactured items [3,4,5,6]. Some additional studies that have appeared in the literature are as follows. Chung [6] investigated bounds for production lot sizing under machine breakdown conditions. Assuming that the deterioration of the production process follows a random process, Porteus [8,9] and Rosenblatt and Lee [10] investigated the effect of quality on lot sizes in Economic Order Quantity (EOQ) and Economic Manufacturing Quantity (EMQ) models, respectively. While the above authors have relaxed the perfect quality assumption, they generally presume that the imperfect quality parts can be reworked at some cost to satisfy demand for the items. Paknejad, Nasri, and Affisco [16] present an EOQ model for a situation where two distinct demands for conforming and non-conforming parts are placed on a stable production process with a known process capability, represented by the proportion of non-conforming items produced.

The papers cited in the last two paragraphs assume that the unit holding cost is proportional to duration of time an item is kept in inventory to meet a future demand. In the present work we study the more realistic case where holding cost follows a nonlinear function of time for the situation described in the following paragraph.

Let us consider a scenario where the vendor operates a process that is in statistical control. That is the process generates a known constant proportion of non-conforming items, \( \theta \). Such an assumption has been made previously in the literature by Affisco, Paknejad, and Nasri [1] and Cheng [3] in the context of Joint Economic Lot Size (JELS) and EMQ models, respectively. We also assume that the holding cost follows a nonlinear function of time similar to that used by Weiss [14]. The vendor ships on a lot-for-lot basis in response to orders from the purchaser. Under these circumstances and upon receiving the items from the vendor, the purchaser applies a 100% quality inspection policy. We assume that the purchaser’s quality inspection process is perfect so that all conforming products in a lot are accepted to satisfy demand in a primary market and all non-conforming products are rejected and sent to a warehouse to satisfy demand for non-conforming parts in a secondary market. Inspection cost per lot is assumed to be a linear function of lot size. Furthermore, shortage cost for the conforming parts are assumed to be high. Hence, shortages are not allowed for conforming parts in the primary market while permitted for non-conforming parts in the secondary market. Shortage cost for non-conforming parts is levied based on the number of units short, irrespective of the duration of shortage. Non-conforming leftover units at the end of each cycle, if any, are sold (or disposed of) all at once for a fixed price (or disposal cost) per non-conforming unit.

For the scenario described above, in the next section we present the structure of the inventory system and the underlying conditions leading to shortages or excess units of non-conforming parts. We then present the explicit relationships for the optimal lot size and optimal total inventory cost.
incurred by the purchaser in both markets for each of two separate cases of shortages or excess units of non-conforming parts which may arise. Finally, a summary is provided in the last section.

2. MODEL AND ASSUMPTIONS

The foundational model considered in this paper is the classic EOQ with deterministic demand, constant setup cost, and nonlinear holding cost, developed by Weiss [14] and applied by Ferguson et al [7] for approximation of the optimal order quantity of perishable goods. Assuming that the cumulative holding cost for one (conforming) unit held during \( t \) interval of time is \( H(t) = C_h t^\gamma \), where \( C_h \) and \( \gamma \geq 1 \) are constants, the average inventory cost per unit time, \( AC_{\text{Weiss}}(Q) \), the resulting optimal lot size, \( Q_{\text{Weiss}}^* \), and the corresponding optimal average inventory cost per unit time, \( AC_{\text{Weiss}}^*(Q) \), for Weiss’ model are given by

\[
AC_{\text{Weiss}}(Q) = \frac{D K}{Q} + \frac{Q^\gamma C_h}{(\gamma + 1) D^{\gamma-1}},
\]

\[
Q_{\text{Weiss}}^* = \sqrt[\gamma]{\frac{1 + \frac{1}{\gamma}}{\gamma}} \frac{D K}{C_h},
\]

and

\[
AC_{\text{Weiss}}^*(Q) = \sqrt[\gamma]{\frac{1 + \frac{1}{\gamma}}{\gamma}} D K^\gamma C_h,
\]

where

\( D = \) demand per unit time (in units),

\( K = \) setup cost per setup,

\( C_h = \) cumulative holding cost per (conforming) unit per unit time (year),

\( AC(Q) = \) average inventory cost per unit time,

\( Q = \) lot size per order,

Please note that equations (2) and (3) simply reduce to the corresponding results of the classical Wilson’s EOQ model [1] when \( \gamma = 1 \).

Implicit in the above derivations is the conjecture that all units produced by the vendor conform to specifications and are of acceptable quality. Now, assume this is not the case. Specifically, assume that the vendor’s production process is in statistical control so that it generates a known, constant proportion of non-conforming units, \( \theta \). Upon receiving the parts from the vendor, the purchaser conducts a full inspection of the entire lot at a cost of \( V \) dollars per lot, where \( V \) is a
linear function of lot size. Further assume that the purchaser’s inspection process is precise, and that all conforming parts identified are used to satisfy demand of the primary market while the rejected parts are sent to a secondary market to satisfy demand for non-confirming parts in that market. In addition, assume that shortages are not permitted at the primary market but allowed at the secondary market. Finally, assume that the leftover non-conforming units, after demand of secondary market is fully satisfied, if any, are sold (or disposed of) all at once at the end of each inventory cycle.

Based on this scenario, we use the following additional notations and adjust the behavior of Weiss’s inventory system [14] with nonlinear holding cost for two separate cases of shortages and excess units of non-conforming parts at the secondary market.

Let

\[ H'(t) = C_h' t', \]  
where \( C_h' \) and \( \gamma \geq 1 \) are constants,  
\( H'(t) \) = cumulative holding cost per (non-conforming) unit per unit time,  
\( \theta \) = Proportion of non-conforming parts in each lot,  
\( \rho = \frac{\theta}{1-\theta}, \)  
\( D' = \text{Annual demand for non-conforming parts in units}, \)  
\( V' = k + vQ = \text{Inspection cost per lot}, \)  
\( V'_i = \text{Non-conforming disposal cost per unit leftover at the end of cycle}, \)  
\( V'_s = \text{Non-conforming selling price per unit leftover at the end of cycle}, \)  
\( \pi' = \{ V'_i \text{ if disposed or } (-V'_s) \text{ if sold} \}, \)  
\( \pi' = \text{Non-conforming shortage cost per unit short, irrespective of the duration of shortage}, \)  
\( T = \text{Cycle time} = \frac{(1-\theta)Q}{D} = \frac{Q}{D(1+\rho)}, \)  
\( t_1 = \text{Min}\left\{ \frac{\theta Q}{D'}, T \right\}, \)  
\( t_2 = T - t_1, \)  
\( B = \text{Number of non-conforming parts short at the end of cycle, if any}, \)  
\( L = \text{Number of non-conforming parts leftover at the end of cycle, if any}, \)  
\( C(Q) = \text{Total inventory cost per cycle}, \)  
and  
\( TC(Q) = \text{Total inventory cost per year}. \)

Using the above notations, it can easily be demonstrated that shortages arise at the secondary market when \( \rho < D' / D \) while excess units will be realized when \( \rho > D' / D \). Finally, demand for non-conforming parts will be fully met when \( \rho = D' / D \). These cases are depicted in Figures 1, 2 and 3.
Figure 1. Inventory System for Conforming and Non-Conforming Parts
Shortages of non-conforming parts: \( \rho < D'/D \)

\[
T = (1-\theta)Q/D
\]

\[
t_1 = \theta Q/D' \quad t_2
\]

Figure 2. Inventory System for Conforming and Non-conforming Parts
Demand for non-conforming parts is fully met: \( \rho = D'/D \)
Using Figures 1 and 3 and considering $\rho = D'/D$ as a special case of these, we can simply develop the expressions for the total annual cost as follows.

**Case 1:** Shortages of non-conforming parts: $\rho \leq D'/D$

Consider one cycle of length $T = \frac{(1-\theta)Q}{D} = \frac{Q}{(1+\rho)D}$. Note that the cumulative holding cost if one conforming unit is kept in inventory during the cycle $[0,T]$ is $C_\gamma T^\gamma = \int_0^{(1-\theta)Q/D} C_h \gamma t^{\gamma-1} dt$. During the cycle, conforming inventory level changes with time according to $I(t) = (1-\theta)Q - Dt$. Therefore, average conforming holding cost per cycle is

$$\int_0^{(1-\theta)Q/D} C_h \gamma [(1-\theta)Q - Dt]^\gamma dt = \frac{C_h}{(1+\gamma)D^\gamma} \left( \frac{Q}{(1+\rho)} \right)^{1+\gamma},$$

Likewise, the cumulative holding cost if one non-conforming unit is kept in inventory during the $t_1$ portion of a cycle $[0,t_1]$ is $\int_0^{\theta Q/D} C_h' \gamma t^{\gamma-1} dt$. During the cycle, non-conforming inventory level changes with time according to $I'(t) = \theta Q - D't$. Therefore, average non-conforming holding cost per cycle is

$$\int_0^{\theta Q/D} C_h' \gamma (\theta Q - D't)^\gamma dt = \frac{C_h'}{(1+\gamma)D'^\gamma} \left( \frac{\rho Q}{(1+\rho)} \right)^{1+\gamma},$$

It can also easily be seen that

$$B = (1-\theta) \frac{D'}{D} Q - \theta Q = \frac{Q(D'-D\rho)}{(1+\rho)D}.$$
Therefore, the total average inventory cost per cycle is

\[ C(Q) = K + \frac{C_h}{(1 + \gamma)D'} \left( \frac{Q}{(1 + \rho)} \right)^{1+\gamma} + \frac{C_h'}{(1 + \gamma)D'} \left( \frac{\rho Q}{(1 + \rho)} \right)^{1+\gamma} + \frac{Q(D' - D\rho)\pi'}{(1 + \rho)D} + k + vQ \]  

(7)

Multiplying (7) by the number of cycles per year, \( \frac{D(1 + \rho)}{Q} \), after some simplifications, we find the total average annual cost, TC(\( Q \)), as follows:

\[ TC(Q) = \frac{D(K + k)(1 + \rho)}{Q} + D \left( \frac{Q}{1 + \rho} \right)^{\gamma} \left[ \frac{C_h}{D'} + \frac{\rho^{1+\gamma}C_h'}{D'} \right] + (D' - D\rho)\pi' + vD(1 + \rho) \]  

(8)

When \( \rho \leq \frac{D'}{D} \), the optimal values for the order quantity, \( Q^* \), and the total average annual cost, TC(\( Q^* \)), are found by using classical optimization and algebra as follows:

\[ Q^* = (1 + \rho)^{1+\gamma} \sqrt{\frac{(1 + \gamma)D'(K + k)}{C_h + C_h'\rho^{1+\gamma} \left( \frac{D}{D'} \right)^{\gamma}}} \]  

(9)

and

\[ TC(Q^*) = (1 + \gamma)D'(K + k) \left[ \frac{C_h}{D} + \frac{\rho^{1+\gamma}C_h'}{D'} \right] + (D' - \rho D)\pi' + vD(1 + \rho) \]  

(10)

Please note that equations (9) and (10) simply reduce to the corresponding results of the traditional EOQ model with constant holding cost and imperfect quality subject to distinct demands for conforming and non-conforming items developed by Paknejad et al [16] when \( \gamma = 1 \). Furthermore, they reduce to Weiss’ EOQ model [14] with non-linear holding cost represented by equations (2) and (3) when the quality of the ordered items is perfect (\( \theta = \rho = 0 \)) and no inspection takes place (\( v = 0 \), and \( k = 0 \)). Finally, they simply reduce to the corresponding results of the classical Wilson’s EOQ model [1] when \( \gamma = 1 \), quality is perfect (\( \theta = \rho = 0 \)), and no inspection is needed (\( v = 0 \), and \( k = 0 \)).

When \( \rho = \frac{D'}{D} \), equations (9) and (10) will lead to the following results

\[ Q^* = (1 + \rho)^{1+\gamma} \sqrt{\frac{(1 + \gamma)D'(K + k)}{C_h + C_h'\rho}} \]  

(11)

and
\[ TC(Q^*) = \sqrt{1 + \gamma} D' (K + k) \left[ C_h + C_h' \rho \right] + vD(1 + \rho) \] (12)

**Case 2:** Excess units of non-conforming parts, \( \rho \geq D'/D \)

In this case, following the same procedure as before, average conforming holding cost per cycle is given by equation (4). Again, the cumulative holding cost if one non-conforming unit is kept in inventory during a cycle \([0, T]\) is \( C_h \int_0^{(1-\theta)D/D} C_h' y^{-1} dt \). During the cycle, non-conforming inventory level changes with time according to \( I(t) = \theta Q - D' t \). Therefore, average non-conforming holding cost per cycle is

\[ \int_0^{(1-\theta)D/D} C_h' \gamma (\theta Q - D' t) y^{-1} dt = C_h' Q \left( \rho - \frac{D'}{D} \left( \frac{\gamma}{1 + \gamma} \right) \right) \left( \frac{Q}{D(1 + \rho)} \right)^\gamma, \] (13)

It can easily be shown that

\[ L = (D\rho - D') \left[ \frac{Q}{D(1 + \rho)} \right] \] (14)

Therefore, the total inventory cost per cycle is

\[ C(Q) = K + \frac{1}{(1 + \gamma) D'} \left[ C_h + C_h' \left( \rho(1 + \gamma) - \gamma \frac{D'}{D} \right) \right] \left( \frac{Q}{1 + \rho} \right)^{1 + \gamma} + (D\rho - D') \left[ \frac{Q}{D(1 + \rho)} \right] V' + k + vQ \] (15)

Multiplying (15) by the number of cycles per year, \( \frac{D(1 + \rho)}{Q} \), yields the total annual cost as follows:

\[ TC(Q) = \frac{D(K + k)(1 + \rho)}{Q} + \frac{1}{(1 + \gamma) D'^{-1}} \left[ C_h + C_h' \left( \rho(1 + \gamma) - \gamma \frac{D'}{D} \right) \right] \left( \frac{Q}{1 + \rho} \right)^\gamma \\
+ (D\rho - D') V' + vD(1 + \rho) \] (16)

Please note that in the above equation \( V' = V_1' \) if leftover non-conforming parts at the end of cycle are disposed of and \( V' = -V_2' \) if they are sold.

Again, when \( \rho \geq \frac{D'}{D} \), application of classical optimization techniques to equation (16), followed by simple algebraic manipulations, yield the optimal order quantity, \( Q^* \), and optimal total annual cost, \( TC(Q^*) \), as follows:
\[ Q^* = (1 + \rho)^{1+\gamma} \left( \frac{1 + \frac{1}{\gamma} D' (K + k)}{C_h + C_h' (1 + \gamma) \rho - \gamma \frac{D'}{D}} \right) \]  

(17)

And

\[ TC(Q^*) = (1 + \frac{1}{\gamma}) D (K + k)^{1+\gamma} \left\{ C_h + C_h' \left[ (1 + \gamma) \rho - \gamma \frac{D'}{D} \right] \right\} + (D \rho - D') W' + vD (1 + \rho) \]

(18)

When \( \rho = \frac{D'}{D} \), as in case 1 discussed before, equations (17) and (18) also reduce to equations (11) and (12).

Please also note that when stock can be stored indefinitely to meet future demand, that is \( \gamma = 1 \), then results of this paper simply reduce to the corresponding relationships developed by Paknejad et al [16]. Furthermore, when \( \gamma = 1 \) and quality is perfect (i.e. \( \rho = \theta = 0 \)), then the results discussed in this paper become identical to those presented by Weiss [14] given by equations (2) and (3).

4. SUMMARY

A new line of inquiry into Economic Order Quantity models was embarked upon by Paknejad et al [16] for a situation where two distinct demands (one for conforming parts in a primary market and another for non-conforming parts in a secondary market) are placed on a stable production process with a known process capability. Assuming that the holding cost is constant, the authors applied classical optimization techniques to derive closed form relationships for the optimal lot size and optimal total relevant inventory cost for two separate cases of shortages and excess units of non-conforming parts in the secondary market. The constant holding cost assumption, which is customarily used by researchers in the vast majority of inventory studies, in essence implies that the stock can be stored indefinitely to meet a future demand - which is not always the case.

The present research generalizes the results appeared in Paknejad et al [16] to the case of perishable items for which holding cost is better treated as a nonlinear function of the amount of time an item is held in inventory. Using a scenario similar to the previous work, this paper presents the underlying conditions which lead to shortages or excess units of non-conforming items in the secondary market. For each case, the paper also develops explicit expressions for the optimal lot size and optimal total inventory cost incurred by the purchaser in both markets. It is shown that the more general results of this paper are reduced to the corresponding results of the previous work, where stock can be stored indefinitely to meet future demand.

Acknowledgement: This research was supported by a Summer Research Grant from the Frank G. Zarb School of Business.
REFERENCES

An Optimization-Based Heuristic for a Recreational Hiking Problem
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Abstract

A bi-modal problem occurring recreational hiking is presented, formulated, and solved using an heuristic approach. The problem has similarities to routing problems in business in which there are two modes of transport, e.g., flying/driving, or driving/walking. The problem decomposes into a set covering problem (SCP) and an asymmetric traveling salesperson problem (ATSP), corresponding respectively to a hiking time objective, and a driving distance objective. A solution algorithm is developed that considers the hiking time objective to be dominant, but considers all alternate optimal solutions of the hiking time problem as inputs to the driving distance problem. The problem is manageable enough to be used as a case in a course in analytics or optimization, with models developed and solved in a spreadsheet environment, with or without additional programming.

Introduction

This paper presents a driving/hiking (bi-modal) optimization problem motivated by recreational hiking. It has strong connections to the well-known set covering problem (SCP) and the traveling salesman problem (TSP). Because of the bi-modal nature of the problem and logistics of performing certain types of hikes, the TSP aspect of the problem becomes asymmetric. The problem structure has application to routing problems in business where there are two modes of transport, e.g., flying/driving or driving/walking.

The motivating problem here is the climbing of the 48 peaks above 4000 feet in the State of New Hampshire (Figure 1). Many hikers aim to become part of the “club” who have scaled these peaks. The question addressed in this paper is to find the “optimal” tour through these peaks, considering both hiking and driving objectives. To get a more specific, given a set of peaks connected by trails and parking areas, determine the set of hikes to perform (each hike covers one or more peaks), as well as the sequence of hikes, so as to minimize an objective involving both driving and hiking aspects.

This paper presents a precedence-based dual objective approach (each objective corresponding to a mode of transportation), which is implemented using traditional a traditional programming language and optimization engine, as well as a spreadsheet-based approach. Given the manageable size of the problem and accessibility with spreadsheets, it becomes a good example for use in courses in Prescriptive Analytics/Optimization, Operations Research, Management Science, and the like.

The root problems underlying this problem include the previously mentioned SCP and TSP (e.g., Applegate et al. 2007; Gutin 2007). In addition, the Vehicle Routing Problem (e.g., Golden 2008), Arc Routing Problems (e.g., Dror 2000), Orienteering Problem (Golden 1987), Prize-Collecting Traveling Salesman Problem (Balas 1989), and the Park and Loop problem (Gussmagg-Pfliegl et al. 2011) are
related. A couple of recreational routing problems are also present in the literature (e.g., Cerna et al. 2014; Gavalas et al. 2014).

Problem Definition and Formulation

This problem occurs on two inter-connected networks. One network is a network of parking areas, connected by roads. The other network is a network of peaks, connected by trails. Some trails also have connections to parking areas (Smith & Dickerman 2012). It is useful to define the overall network as $G$, with two sub-networks $G_1$ (road network) and $G_2$ (trail network). $G_1$ is the set of parking areas, which will be denoted by $V_1 = \{P_1, P_2, \ldots, P_m\}$, where $P_i$ is parking area $i$, and $E_1$ the set of roads connecting the parking areas. Similarly, $G_2$ is the set of peaks ("customers" in traditional TSP language), each of which must be visited at least once. The peaks will be denoted as $V_2 = \{C_1, C_2, \ldots, C_n\}$, and $E_2$ the trails linking the peaks as well as the parking areas. Figure 2 displays an example.

The concept of a hike should be explained. The car is driven to a parking area $P_i$. A hike is performed, defined visiting one or more peaks. There are two possibilities for the end of the hike. A loop or cyclical trip is when the hikers return to $P_i$, and then continue on to another parking location. A chain trip is when the hikers end at a different parking area, say $P_j$. The chain trip is a key aspect of this problem which differentiates it from other problems in the literature, yet it is a very common occurrence in this application. In order to perform a chain hike, both hikers drive to $P_j$, leaving one car there. Then they drive to $P_i$ and leave on the hike. Finishing the hike at $P_j$, they drive back to $P_i$ to retrieve the other car.

Practical feasibility of chain trips depends on the application. In the motivating setting, it is common, not only to have two hikers (from a safety and logistical aspect), but also that some hikes are more naturally done as one-way hikes. This has the potential to reduce hiking time considerably. Having two cars increases the total mileage driven, though not necessarily the time. So it depends on the objective whether this is an issue. Chain trips may be useful in other settings as well, for example if the “parking” areas are airports, and customers are to be visited on one-way trips between airports. Another example may occur with bike or car sharing programs, where the pick-up and drop-off locations can be different.

For this paper, possible hiking trips are assumed to be developed in advance. This is very reasonable, as there are many hiking guides available and there tends to be a finite number of reasonable trips. Therefore, the problem becomes one of selecting which trips to perform, and then how to sequence the trips so that the overall objective is optimized. The objective can be time-based or distance-based, or a weighted combination.

Notation is provided below:

- $i = 1, \ldots, m$: trip index (hiking trips)
- $j = 1, \ldots, n$: customer (peak) index
- $c_i$: cost of trip $i$ (e.g., time, distance)
- $d_{ik}$: cost of driving from trip $i$ to trip $k$
- $a_{ij}$: $1$ if trip $i$ visits customer (peak) $j$; $0$ otherwise
The direction of travel may affect the trip cost (e.g., terrain features). It is common, therefore, to define a trip in each direction, especially for chain trips (cyclical trips can be done in the fastest way with no impact on driving logistics). The driving distance matrix $D$ is a matrix of trip-trip distances. This matrix is in general asymmetric, especially in the presence of chain trips.

Decision variables for the problem are defined as follows:

\[ x_i = 1 \text{ if trip } i \text{ is selected; } 0 \text{ otherwise} \]

\[ y_{ik} = 1 \text{ if trip } k \text{ follows trip } i \text{ (} k \neq i \text{); } 0 \text{ otherwise} \]

The formulation of the problem is provided here:

\[
\min \sum_i c_i x_i + \sum_{i \neq j} d_{ij} y_{ik}
\]

subject to

\[ \sum_j a_{ij} x_i \geq 1 \quad j = 1 \ldots n \quad (1) \]

\[ \sum_{k \neq i} y_{ik} - x_i = 0 \quad i = 1 \ldots m \quad (2) \]

\[ \sum_{i \neq k} y_{ik} - x_k = 0 \quad k = 1 \ldots m \quad (3) \]

subtour elimination constraints

\[ x_i, y_{ik} \in \{0,1\} \]

The objective is the weighted sum of the hiking cost and the driving cost. Constraints (1) ensure that every customer (peak) is visited at least once. These are the traditional set covering constraints. Constraints (2) and (3) make sure that the selected trips are connected to the actual driving network. That is, if a hike is not selected, no drives should be selected to or from that hike. Similarly, if a hike is selected, there must be one drive to that hike and one drive away from that hike. The subtour elimination constraints ensure that the hikes selected form a full cycle.

Weights on the objective allow for differential importance of the hiking and driving objectives. For the case here, the problem is solved assuming that the hiking objective takes precedence over the driving objective. This allows the problem to be divided into a Phase I problem, which is essentially a set covering problem to select the hikes that minimize the hiking objective. Then these selected hikes are passed to Phase II, which becomes essentially an asymmetric traveling salesperson problem. The next section discusses the heuristic approach to the solution.
Implementation

The heuristic approach was implemented in two ways. The first way was using a traditional programming language (C), along with callable optimization routines (CPLEX). This is the more robust approach. But, because of the motivating application and the manageable size of the problem, the problem was also developed and addressed using a spreadsheet-based approach using Excel and Visual Basic for Applications (VBA). This latter approach, in whole or in part, can be incorporated into classes in Business Analytics and similar courses that cover optimization. Using the spreadsheet-based model, students can experiment with different solutions and approaches, including side constraints and/or different objectives, and also see the benefit in some cases of a higher-powered solution approach.

Possible hiking trips are pre-defined by the user. Each node in V2 (i.e., each peak or customer) must be in at least one hike to ensure feasibility. Then the set covering problem (SCP) is solved to identify the set of hikes that minimizes the hiking objective (in this paper, total hiking time). These selected hikes are then sequenced to minimize the total driving time. This in general is an asymmetric traveling salesperson problem (ATSP). In this paper, the well-known Cheapest Insertion heuristic was used to solve the ATSP to ensure quick solution time with good solution quality. This heuristic is sensitive to the starting node, so the heuristic was used from each starting node, and the best solution kept.

In the traditional programming-based approach, all the alternate-optimal solutions to the SCP were found using a modified branch-and-bound approach. Each of these solutions (sets of selected hikes) was passed to the ATSP heuristic to find the sequence and driving distance. The best-found solution is then the solution with the lowest hiking time, and among those solutions, the one with the shortest driving distance.

In the spreadsheet-based approach, the SCP is solved using the A matrix of trip definitions along with the trip cost vector. Total hiking time is minimized by selecting the optimal set of hikes to perform. This can be done quite easily with the built-in Solver in Excel, at least for the problem size in this case. This itself is a nice application or case study for a class in analytics or optimization.

Once the set of hikes has been determined, the hikes must be sequenced in order to make the driving distance as small as possible. This can be done a couple of ways in a spreadsheet. This is an asymmetric TSP, which is not the easiest problem to set up in a spreadsheet environment. However, VBA code was written to implement the Cheapest Insertion heuristic. So the chosen hikes are input to the Cheapest Insertion heuristic, which then sequences the hikes. Another approach in the spreadsheet is to use Solver’s built-in Evolutionary Solver engine. The decision variables would be the sequence number of each trip, with the costs being the distances between trips. This aspect is also a nice application for a course in analytics or optimization.

Results

There are 48 peaks above 4000 feet in New Hampshire. Each peak has at least one trail leading to the summit. Based on these peaks, 42 hikes were defined, covering between 1 and 14 peaks, with varying hiking times. Hiking time is expressed in hours. Similarly, there are 25 parking areas identified, and the distance between parking areas was identified.
Using the traditional approach, nine alternate-optimal solutions to the SCP problem were found. For each one, the ATSP was solved to find the minimum driving distance (i.e., the best sequence of the selected hikes). Summary results are shown in Table 1. The minimal hiking time was found to be 138.75 hours. The best driving time was found to contain 297 miles of inter-hike driving (i.e., driving from one hike to the next), and 138 miles of intra-hike driving (i.e., driving to coordinate the logistics of chain hikes). Considering that two cars are used for the inter-hike driving portion, the total driving miles is $297 \times 2 + 138 = 732$ miles.

Small differences in hikes may not result in large changes in hiking time, but may make it possible to reduce the driving objective. As an experiment, the criteria for what determines an “alternate” optimal solution was relaxed somewhat. All SCP solutions within $\alpha\%$ of optimal were considered. Allowing $\alpha=0.5\%$, hiking time was between 138.75 and 139.44 hours, and resulted in 125 different sets of hikes. Running these 125 different sets of hikes through the ATSP heuristic resulted in a best-found driving distance of 272 miles of inter-hike driving, 138 miles of intra-hike driving, for a total of 682 miles.

Conclusions and Possible Extensions

This paper presented a recreational hiking problem as a dual-objective optimization problem. An heuristic approach was developed for its solution, and example results presented. The problem is size-manageable enough to be implemented in a spreadsheet environment, making it a good application for classes in analytics and/or optimization.

There are a couple of possible extensions. Obviously one could use different heuristics for the ATSP. Given the relative small size of the problem, the one used here was deemed adequate. Another possibility is to consider a possibility when performing a chain hike. Suppose two hikers perform a chain hike, but before driving from the end of the hike back to the beginning, they perform one or more cyclical hikes, starting from the endpoint of the chain hike. This has the potential to decrease the total driving required. The formulation would need to account for these possibilities, and the solution approach altered.

Treating the two objectives simultaneously, with appropriately selected weights, would generalize the solution approach. This paper takes advantage of the hiking time objective having precedence over the driving objective, and compensates for that simplification by considering all the alternate-optimal sets of trips. If the two objectives were combined, this latter step would not be necessary, but the overall problem becomes more difficult because there is no longer the clean decomposition into a SCP and ATSP.

In this paper, the possible hikes (trips) are pre-defined by the user. This makes sense in the current application, as there is a relatively small universe of reasonable hikes. Embedding the trip-definition into the formulation and algorithm may yield somewhat better solutions, at the expense of a more complex problem with higher solution difficulty.

References


Figure 1. New Hampshire’s “4000-footers” (source: Google)
Figure 2. Illustration of Road and Trail Networks
Table 1. Summary of Results

<table>
<thead>
<tr>
<th>Solution</th>
<th>Hike Time (hrs)</th>
<th>Intra-Hike Driving (mi)</th>
<th>Inter-Hike Driving (mi)</th>
<th>Total Driving (mi)</th>
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<tr>
<td>1</td>
<td>138.75</td>
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<td>299</td>
<td>760</td>
</tr>
<tr>
<td>2</td>
<td>138.75</td>
<td>138</td>
<td>303</td>
<td>744</td>
</tr>
<tr>
<td>3</td>
<td>138.75</td>
<td>180</td>
<td>362</td>
<td>904</td>
</tr>
<tr>
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<td>204</td>
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</table>
A CASE STUDY OF MS / OR APPLICATIONS

Based on a Consultant’s career in MS / OR applications, with emphasis on successes, failures, and Management incapability to adapt and/or change. Although practicable applications may precede implementation, even by years, without courage to apply MS / OR to Client’s needs, little progress in adaptation of these procedures will be achieved. This longitudinal look vs short-term, may guide prospective entrants in a choice of a consulting career utilizing MS / OR.

Research Assistant – University of Arizona

Markov Chain Model – Developed to determine water priority rights and their effect on farm planning in the San Carlos Irrigation and Drainage District in Central Arizona.

- **Successes:** Initial stream flow data limitations were overcome by finding tree ring studies for 350+ years, correlated with flow data allowed meaningful findings and recommendations. *Note: MS Dissertation from this work awarded best MS Thesis by Western Agricultural Economics Association.*

- **Failures:** - Moving on to Doctorate program at Oklahoma State University did not allow follow-up training on use of recommendations for District officials.

Research Associate – Oklahoma State University

Discriminate / Cluster / Factor Analysis - Use of socio-economic county data to predict success of watershed development in Oklahoma,

- **Successes:** - Developed model determining probability of success by watershed districts applying for developmental assistance. Given limited planning resources of state & federal agencies, also that PL566 required local district to come up with local resources, many districts found low probability of success.

- **Failures:** - State officials slow to implement recommendations, plus favored political considerations.

Leader - Northeastern Resources Group - Economic Research Service - USDA

Input-Output Model - My role developing I-O coefficients, for water pollution emanating from upstream agricultural-related activities, for select River Basin Studies in North Atlantic Region.

- **Successes –** Led to also developing open-space and recreational use coefficients, creating value for total contribution of rural lands, other than agriculture and forestry. *Note: New Jersey later adopted open-space tax-breaks to enhance visual quality using said coefficients.*

- **Failures -** Since data limitations on pollution runoff by type of land use, utilization limited.

Discriminate /Factor Analysis - Use of socio-economic county data to predict success of government programs.

- **Successes:** - Provided optimum allocation of scarce planning resources to highest performing watershed districts in North Atlantic Region.
A CASE STUDY OF MS / OR APPLICATIONS

- Failures: - Although model proven successful for other government programs, leadership in government agencies felt complied to share resources equally. When taken to Legislators, they indicated equal distribution to constituencies only politically acceptable. My analysis indicated .30% reduction in cost could be obtained if adopted.

Armour Foods

Linear Programming – Applied to hotdog, lunch meat & sausage making, calculating least-cost formulation as price of ingredients varied. Similarly, applied to turkey feed formulation.

- Successes – Hotdogs etc., by bringing LP in-house, then specializing to each processing plant’s ingredient price relatives, provided considerable cost savings.
- Failures – Increasing kilo-calories/ton turkey feed toward maximum turkeys could metabolize, resulted in body growth > leg strength, thus found 5,000 turkeys unable to stand, so had to process into turkey burgers at a loss. Note: Small loss given processed 3-million turkeys annually.

Align Production / Marketing Costs – Applied to 2,500 products, producing $3.5 b sales, finding 30% or 750 products not-profitable, thereafter eliminated without reducing sales.

- Successes – Applied following year increasing profits 5%, of which management received 25% bonus.
- Failures – Marketing continued to add niche products when possible, then delay by management in determining to close production thereof.

Socio-Economic Distribution Center / Plant Location Model - Optimizing location of new plants or distribution facilities significantly reduce capital requirements, while relocating or closing inefficient ones save significant operating costs.

- Successes - Balancing access to livestock producing county data to that of eligible and trained workforce availability proved essential. Locating new and/or purchased plants next to competitor’s oldest and most inefficient plant became best strategy. Similarly, optimizing both capital and operating costs with LP spatial trade-offs, determined distribution facility locations.
- Failures – Given Model solutions indicating major changes requiring large capital infusions, but with major cost savings more than offsetting, management short-term view and risk aversion delayed implementation of findings.

Simulation Model – Traditionally meat scientists determine cutting carcass into cuts, optimizing formation each cut or meat product. Also, cutting chart used as guide by purchaser of animals. Applying daily market price each cut, determining relative difference between cuts (ham vs bacon for example) found can maximize value without compromising quality of cut.

- Successes – Simulating daily prices vs traditional for 6-months at 1-plant, revealed $0.5 m greater profit, if applied 10-plants under operation, would yield $10 m additional profits.
- Failures – Management never implemented. Due to additional management errors, within couple years Armour was broken into parts and sold.
A CASE STUDY OF MS / OR APPLICATIONS

- Footnote: Many years later, another meat processor implemented similar program, thus becoming largest USA meat processor, just recently bought (multi-$b) by Chinese.

**MS Association**

Formed Phoenix Chapter of MS, first of kind in SW.

- Successes – Grew from 3-members to 27 members in 3-years.
- Failures – Upon my leaving area, few years later dissolved.

**Cudahy Foods**

Simulation Model – Similar application as with Armour Foods, resulting in projected profitability, leading to plant sale offer to consultant, providing chance to prove Model effectiveness.

- Successes – Consultant able to raise required $10 m purchase price through NYC contacts. Advantage Controller of capital provider only check books every 6-months, with full control of operations by myself, as Buyer.
- Failures – Turned out after investigation source of funds Mafia. With going head price at time only $25,000, backed out of purchase.

**Arizona State University**

Associate Professor, Food Industry, utilizing experience in agricultural resources and food industry, at less income than consulting, due to 3-children in college, thus tuition benefit resulted in greater net. Provided opportunity to introduce MS / OR through courses and research.

- Successes:
  1. Revived Alpha Gamma Rho fraternity in roles of faculty sponsor, landlord, house father and student advisor.
  2. Introduced new course utilizing Simulation Model, with each group having management, marketing, production and finance members, with best performing group receiving highest grade, a new concept since students used to grades on individual performance, not like life in business environment.
  3. Kufra Marketing – Summer international assignment to an oasis in Libya, utilizing MS procedures moving ag-products efficiently to Benghazi on Mediterranean coast.
  4. Swaziland Conservation – Team Leader role as Economist correlating findings by Agronomist, Soil Scientist, Conservationist and Sociologist on managing / optimizing conservation practices.

- Failures:
  1. AGR became defunct a year after left ASU.
  2. ‘A’ students on lower graded groups rebelled, as may look bad if applying for MS.
  3. Political considerations denied some gains.
  4. USAID Regional policies denied some gains.
A CASE STUDY OF MS / OR APPLICATIONS

Iran – International Sheep & Goat Institute

Director, ISGI, utilizing OR procedures to correct studies of Animal Scientists before. Iran, with 28 breeds sheep & 12 breeds goats (more than any country in world), provided vast opportunity for crossbreeding, but so many possibilities had reported too few numbers per trial, thus insignificant findings. Also, meat quality of breeds not scientifically evaluated.

- Successes:
  1. Decreasing number crossbreeding trials, while increasing numbers per trial, could then report significant findings.
  2. Provided cooking demonstration to 100 officials of lambs cooked over charcoal pits as follows: A = fat-tail pure bred; B = fat-tail cross-bred; C = tail-off pure bred; D = tail-off cross-bred. Questionnaires concerning looks, taste, moisture, tenderness of lambs, each marked A, B, C or D found results opposite local beliefs.

- Failure: Could not complete 2-year assignment due to Iranian revolution underway having to evacuate hastily.

Saudi Arabia – US Department of Treasury

Development Program Officer, USREP / JECOR, manage and coordinate with Teams in 7-Ministries & Agencies of Saudi government.

- Successes - First to utilize satellite imagery in Saudi Arabia for assigning random sampling. New procedure determined agricultural production capability significantly greater than former list sampling procedure allowing change in development priorities & resource allocations.
- Failures - Could not complete 2-year assignment due to better offer from Saudi private sector business opportunity. Many years later, USREP / JECOR priced itself out of business, primarily due to unreasonable benefits demands by USA expats.

Saudi Arabia – Arieb Agriculture

Vice President & Managing Director developing business plan to take advantage of new priorities in ag-sector development. Travel required sourcing equipment suppliers in EU, Japan, USA; skilled employees in Australia, Jordan, USA; and negotiating financing in Bahrain, EU and USA.

- Successes:
  1. Quickly became World largest distributor of center pivot irrigation systems. 3rd year sales $10 m profit, with my 5% bonus of $0.5 m, by introducing employee incentive system for each division, based on contribution.
  2. Later received US President Medal for small business steel exports, selling / installing grain bins to Saudi Arabia, with storage capacity 760,000 metric ton.
  3. Became Group V. P. for Arieb Development Ltd., managing 4-divisions with $200 m revenues.

- Failures: Although developed business plans for each division, including required allocation of resources to attain set goals, Board would not approve resource requirements,
A CASE STUDY OF MS / OR APPLICATIONS

in fact, would steal resources from winners, providing to losers, thus resigned, not wishing to be a party contributing to failure.

Jordan – Consulting Assignment

Agro-Business Sub-Sector Assessment as Team Leader, providing Agro-Business survey findings and report development, with implementation recommendations. Later, develop proposal, strategy, scope of work and budget, seeking funds from IMF for follow-up 2-year study of select sectors.

- Successes – None really. Jordan government budgetary shortage did not allow implementation of recommendations.
- Failures - IMF did not allocate funds for follow-up proposed study.

Costa Rica – Consulting Assignment

Costa Rica Fruits Marketing to USA assessment required interviewing producers, processors and exporters capabilities, determining quality and price, when competitive during year, versus other USA imports.

- Successes – Frozen and/or freeze dry fruits found able to compete on seasonal basis.
- Failures – Unfortunately, as a small producer, fresh fruits not competitive in most seasons.

Ghana – Consulting Assignment

As adviser to Ministry of Agriculture, under funding by FAO/UNDP/WB to Nathan Associates whom I was sub-contractor, soon found had many to report to, including M of A officials. Thus, imperative to utilize OR procedures keeping well ahead of management in solving under development problems. Securing adequate data became priority developing survey capabilities through random sampling procedures, then applying discriminate and cluster analysis determining extent and solutions to identified problems and opportunities.

- Successes:
  1. Results indicated maize subsidy program unsustainable, subsequently eliminated
  2. Determined cocoa export taxation excessive, subsequently reduced.
  3. Marketing fresh fruits & vegetables via airfreight to Europe markets found feasible.
- Failures:
  1. Additional resources not committed for needed expansion of surveys
  2. Training resources inadequate to needs
  3. Disjointed policies between multiple agencies delayed reviews and progress.

Saudi Arabia - The Economic Bureau

To illustrate varied assignments provided through TEB, following list by Client and Conclusion presented:

<table>
<thead>
<tr>
<th>CLIENT</th>
<th>CONCLUSION</th>
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</thead>
<tbody>
<tr>
<td>Al-Babtain Group</td>
<td>5-Divisions Evaluated; Keep, Revise, IPO</td>
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</table>
A CASE STUDY OF MS / OR APPLICATIONS

Al-Faisaliah Group  Select High-Value Medical Equipment / Market Survey
Al Jazeera Marketing Company  Competitor Valuation Leading to Purchase
Al-Khorayef Commercial Co.  Complementary Products & Services / Regionalization
Al-Madina Carpet Factory  Valuation Leading to Competitor Purchasing
Al-Nakhl Paper Industries  Business Plan Ending with IPO
Al-Sharq Factories Plastic / Paper  Feasibility Study / Expansion / Wrapping Materials
Arab Banking Corporation  Assess Bahrain Economy / Future Prospects
Arabian Oil Company  Study for Contract Services / Reorganization Study
Arabian Springs Mattress Company  Study Led to Purchase by NIC
ARAMCO  Study on Feedstock Pricing
Baghlaf Al-Zafer Company  Galvanizing / Hot / Cold Rolling Mill Evaluation
Bathel Ahair Est.  Low-Cost Housing Feasibility Determined
Council of Saudi CC&I  KSA / African Block Trade Potential Assessment
Euromarche  Company Valuation for Sale
Friends  New Strategy for Elderly
Islamic Development Bank  Restructuring Sierra Leone Development Bank
Itouchu Corporation  5-Studies on Select Products / New Strategy
JETRO  12-Market Studies Various Products
JETRO  Vocational &Technical School for Women Study
JICA  22-Market Studies Various Products / Services
JICA  Riyadh Technical College Instruction Evaluation
JICA  Nurse Education & Employment Study
Ministry Finance & National Econ.  Privatization of KSA Economy
Ministry of Planning  Survey of Private Sector Establishments
Mitsui  GCC – 28 Chemicals / Steel Piles / 8 Products Markets
NADEC  Company Evaluation & Restructuring – 4 Sites
National Glass Industries Company  Administration /Accounting / Financial / MIS Study
NESMA  Feasibility Study Electrical Insulators – GCC & Yemen
Protoplas International  Plastic Car Bumper Repair – Growth Strategy GCC
SAAG  Reorganization Study
Sebai Institute  Medical Training - 7 Institutes / 1 College Feasibility
Tabuk Cement Company  Feasibility / Reorganization / Expansion Studies
United Parcel Service  Market / Feasibility Studies Led to Opening in KSA

- Successes – Where top management paid full attention during study/analysis, then response to findings were significant and more often implemented.
- Failures – Where data and resources limited, as well as management attention, then response to findings were insignificant and less often implemented.

Sierra Leone - Consulting Assignment

Diagnostic Study of National Development Bank of Sierra Leone for Islamic Development Bank required assessment of their ability to continue servicing rural needs. My analysis indicated need to raise new capital from financial markets, as proven successful in some Asian countries, with most
private bankers I interviewed agreeing, since would require above break-even management to keep afloat, that oversight by markets dictate, as opposed to lax government control of the past.

- **Successes**-After 4-times cash infusions by government had occurred, new directions found a better economic solution, but politically difficult to accept.
- **Failures**-Regional rural needs undetermined due to civil wars underway. 10,000 UN troops could only keep capitol area safe.

**Saudi Arabia- CEO -Advanced Solar Heat Technologies Factory**

My role to develop business and market plans of a start-up enterprise. Travel required to EU, USA, UAE for suppliers while GCC for market potential.

- **Successes**-Proposals made to relevant government agencies brought newsworthy attention while negotiations on territorial rights with suppliers were made.
- **Failures**-Owners lack of capital infusions delayed progress. Thus, sought better opportunities.

**Saudi Arabia- Executive Director-Sudairy Foundation**

My responsibility, present to Board project opportunities viable for target Al-Ghat region, being rural area 250 km NW of Riyadh. This proved most challenging, since Al-Ghat people semi-literate, mostly living off government dole. Travel required to China, EU, India, Malaysia, Thailand, USA for production processes and/or supplier relations, plus UAE in addition to Saudi Arabia for market potential.

- **Successes**-Providers of select equipment and technical assistance found viable.
- **Failures**-Training and capabilities of locals found incapable of implementation.

**Saudi Arabia/ USA-Chairman-Development Group International, LLC**

Formed company registered in USA with 3-Saidi Partners, to create and develop initial ideas, participate in project planning, investment and execution, with implementation of Joint Ventures and/or Project acquisition, as well as business management, providing consultancy services where necessary. In pursuing market opportunities, visited Kuwait, Pakistan and Turkey.

- **Successes**: 1. Through feasibility study performed for *Desam Est.*, formulated business and marketing plan for an ACN petrochemical project, presented to potential Saudi investors, who decided to form new company, including DGI and Desam Est. as members.
   2. DGI allowed new company to have access to our ongoing endeavors, all which I had initiated, including in addition to ACN, Premier Meats, Plastic Compounding, Trade Finance Bank, HR Supply and Video Games.
- **Failures**: Size and scope of new CAN project soon precluded any time and resources applied to project potential stated in 2 above.
A CASE STUDY OF MS / OR APPLICATIONS

Saudi Arabia- CEO-Director-Petrochemical Projects Development Company

PPDC now fully organized, provided shares split 70% to 4-billionaire investors holding 4 seats on Board, while 30% to DGI members holding 4 seats on Board. Thus, as 1 of 4 members of DGI, I would be holding 7.5% of shares in PPDC, plus compensation as CEO, Director. Initial projected valuation of PPDC after development, then full payback to loans and investors after 15-year operations, would be $960 M. Thus my 7.5% share could be $72 M, plus any annual earnings distributed to stockholders by management upon Board approval. Therefore, plenty incentive existed to move this ACN project forward ASAP!

- **Successes:**
  1. Negotiated rights to ACN technology from British Petroleum.
  2. Obtained worldwide statistics on feedstock production, downstream demand from SRI.
  3. Negotiated 100% offtake 20-year marketing agreement with Vinmar International Ltd.
  4. Obtained feedstock allocation commitment from ARAMCO.
  5. Negotiated, selected petrochemical plant construction and maintenance companies
  6. Obtained site location, lease agreement with Jubail Industrial City.
  7. Given above inputs, determined optimum scale plant to maximize returns.
  8. Strategy became build world’s largest, least-cost CAN plant, driving many small plants out of existence thereby taking major market share.

- **Failures:**
  1. Saudi Arabia Minister of Petroleum and Minerals rumored to be changed so political astute Saudi Board members advised to wait on appointment of new Minister, thus project development delayed.
  2. Meanwhile, 2nd Gulf War underway, then feedstock gas shortage resulted losing ARAMCO allocation.
  3. Saudi Board members not interested in moving project to QATAR where available feedstock. Thus, project development activities stopped and PPDC disbanded.

Saudi Arabia-Business Consultant-Athel Saudi Group

Development and execution of an p-Xylene Purified Terephthalic Acid – Polyethylene Terephthalate (PPP) Complex with *Vinmar International Ltd.*

- **Successes:** Utilizing all contacts with previous CAN development process, could proceed rapidly. Also, owners flexible about project location, domestic or foreign.
- **Failures:** Although owners touted required capital no problem, turned out merely agents for others who did not deliver, therefore development activities halted.

International-Project Proposals-DGI

To illustrate varied assignments provided through DG I as reconstructed with only one Partner:

- We joined with *Al Osais Group* in Iraq on potential project engineering and reconstruction of Northern Iraq Refinery.
A CASE STUDY OF MS / OR APPLICATIONS

- Partnered in Riyadh with Engineer Mansour Al-Amri and Abdulaziz Walidad, joining with Dar Al-Riyadh Consultants, on potential study expansion of Gazan Sea Port.
- Infrastructure developments and improvements for Djibouti, at Bab el Mandeb strait, at southern mouth of Red Sea.
- Sharjah/Fujairah Canal & Real Estate Development Project to bypass Strait of Hormuz.
- Petrochemical plant proposed in Oman.
- With Indian Partner / Swiss Investor proposed large oil refinery at southern tip of India.
- Participate in development of new industrial city near Kuala Lumpur, Malaysia.
- With OR Media develop LA Fitness type recreational and fitness center in Riyadh.
- Project to produce disposable needles in KSA, sourcing equipment from Korea.

Summary: Most all these project proposals supposedly included capable investors that could not deliver, and/or political connections that did not deliver. Very typical experience in Middle East consulting.

Conclusions and Recommendations

Early exposure and academic training on MS / OR procedures should be accompanied by publication and presentation at as many venues as possible. This exposure will provide many contacts and references that will assist in determining your career forward. In fact, throughout one’s career, this role should be continued, found to be most valuable as a marketing tool. Note: My personal experience indicates 46 publications and 105 presentations.

Career progression should include public and private sectors, as well as domestic and foreign, for one cannot predict when and where greater opportunities present. There are differences in freedom of expression through publications and presentations, one must be aware, for example, employment or service contracts may specify who controls results of your efforts.

Capability in MS / OR procedures is not sufficient for success in consulting. Good human relations and marketing skills are equally important. If planning to work as an independent consultant, risky but potentially rewarding, one must anticipate >10 proposals for each awarded assignment. Those adverse to risk usually work with a large consulting firm on a permanent basis.

Utilizing MS / OR procedures in consulting is professionally satisfying, but difficulties in selling to management and/or owners, as well as implementing when required, may discourage oneself. In short, balancing satisfaction and discomfort is a career process in consulting.
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Collection Flows Improvements with Contractor’s Obligation Considerations in a Public Postal Network

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The collection flows optimization problem (CFOP) occurs in a last mile postal physical network where goods are collected from various sources (e.g., mailboxes, retail outlets, business customers, etc.) using different collection routes and delivered to various collection centers. It has been defined as one of the strategic priorities on which postal organizations should focus on to deliver high performance with minimum operation costs, given its impacts in changing the cost structure, modifying the capacity available, and in supporting technology-driven services (Accenture, 2015). Thus, a small improvement may result in substantial annual savings (Irnich, 2008). The improvement could be summed up into better utilizing the last mile network to increase the accessibility to end customers and also increasing the market share through providing a competitive pricing structure.
The CFOP provides a public postal service (PPS) organization with collection routes that meet customer’s requirements. These collection routes are often operated by contractors (especially in rural regions) following a competitive bidding process (see Figure 1).

As shown in Figure 1, the PPS organization creates collection routes, estimates their operating costs, and releases them to contractors (3PLs) for bidding to operate them at costs. The contractors evaluate the routes and bid on one or several of them. The PPS organization reviews the bidding cost and matches with the original estimates. If the contractor’s cost is less or equal than the PPS estimates, then the route is awarded to the contractor. In practice, contractors bid on several routes at the same time to get the ones that are manageable and contribute to their profit margin. Bidding on several routes also provides a PPS organization with bundle opportunities to operate the routes at a better cost (economy of scale). In this case, the PPS organization reviews the bundle with contractors and eventually assigns several routes (bundle contract) to one contractor. When a contractor bids on a route, based on the experience, the risks and difficulties that the route might create during the service operation are taken into account, such as road or weather conditions, traffic pattern, time to start and finish, and the truck type and size. As the route complexity is negatively correlated with the number of bids, the bidding process may result to the cost of
operating a specific route that is not attractive (feasible) for a PPS organization. Hence, in developing the last mile delivery collection routes, solutions that lead to a higher bid price given their operational complexities (in terms of risks and difficulties) must be prevented. We refer to this as contractor obligations.

Our work addresses the issue of improving collection flows in a public postal network, while taking into account contractor’s obligations. We formulate the problem as a variant of the multiple depot vehicle routing problem with time windows (Li et al., 2016). The ant colony optimization algorithm (Dorigo and Stützle, 2004) is discussed as a solution methodology and evaluated in a case study that involves a real-life problem faced by a public postal service organization. The case study is discussed with solutions in which whether contract obligations restrictions are considered or not. Overall our approach shows that better feasible routes with reduced level of complexities can be obtained, although at the expenses of additional costs. However, this allows smoothing the bidding process and ensuring that all routes will find a third-logistic organization willing to operate each of them at a reasonable price. Our approach shows also that, by explicitly considering contract obligations, better solutions can be expected in terms of arriving versus cutoff times as well as total travelling distances.

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Competition for Blood Donations: 
A Nash Equilibrium Network Framework

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Abstract

In this paper, we develop a game theory model for competition for blood donations among blood service organizations. The organizations seek to maximize their transaction utilities and compete on the quality of service that they provide at the blood collection sites in different regions. The governing equilibrium concept is that of Nash Equilibrium. We formulate the equilibrium as a variational inequality problem and prove the existence of the equilibrium quality level service pattern. We also provide conditions for uniqueness and provide a Lagrange analysis and interpretation associated with the lower and upper bounds on the quality service levels. An algorithm with nice features for computations is proposed and then applied to a case study consisting of examples of increasing complexity. The results demonstrate that enhanced competition can improve the quality service level and that blood service organizations can also benefit from having collection sites in multiple regions.

Keywords: game theory, blood supply chains, competition for donations, variational inequalities, healthcare
Exact algorithm for the minimum cost vertex blocker clique problem

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1 Introduction

Graphs can be used to effectively model social (Glass and Glass, 2008; Scott, 2012; Wasserman and Faust, 1994), communication (Abello et al., 1999) and power grid systems (Brown et al., 2005; Delgadillo et al., 2010). Graph-based data mining is a key approach in understanding and leveraging big data since graphs may provide abstract representation of complex systems. However, developing tools and techniques that can effectively handle large-scale graph models of data remains a challenging task in this area.

Blocking a set of vertices/edges to bound a particular property of a graph is one of the popular applications in network analysis. There are two types of closely related problems in this area that are minimum vertex/edge blocker (Bazgan et al., 2011a; Ries et al., 2010; Zenklusen et al., 2009) and most vital vertices/edges problems (Bazgan et al., 2011a; Bazgan et al., 2013a; Bar-Noy et al., 1995). In the first one, identifying a subset of vertices/edges with minimum cardinality/cost is desired such that their removal bounds the studied property by some predefined threshold. The second one is looking for a subset of vertices/edges with a given size/budget whose deletion results in a greatest change to the considered property. Both problems have been studied in the context of different graph-related properties such as shortest path (Bar-Noy et al., 1995; Israeli and Wood, 2002; Khachiyan et al., 2008), connectivity (Zenklusen, 2014), maximum flow (Wollmer, 1964; Wood, 1993; Zenklusen, 2010b; Altner et al., 2010), spanning tree (Lin and Chern, 1993; Frederickson and Solis-Oba, 1999; Bazgan et al., 2011b; Bazgan et al., 2013b), assignment (Bazgan et al., 2013c), p-median (Church et al., 2004; Bazgan et al., 2013a), p-center (Bazgan et al., 2013a), maximal covering (Church et al., 2004), chromatic number (Bazgan et al., 2015), independent set (Bazgan et al., 2011a; Bazgan et al., 2015), vertex cover (Bazgan et al., 2011a), matching (Zenklusen et al., 2009; Ries et al., 2010; Zenklusen, 2010a), clique (Mahdavi Pajouh et al., 2014; Becker, 2015; Tang et al., 2016), and dominating set (Mahdavi Pajouh et al., 2015). This line of research has been further extended by incorporating aspects such as leader’s responses to the follower’s actions (Stackelberg game), having stochastic disruption, asymmetric knowledge of both players, and continuance disruption (Lim and Smith, 2007; Bayrak and Bailey, 2008; Losada et al., 2012; Becker, 2015; Tang et al., 2016; Song and Shen, 2016).

The most vital edges shortest path problem has been shown in Bar-Noy...
et al. [1995] to be NP-hard even when all edges have unit length. This problem is formulated as a mixed-integer program in Israel and Wood [2002]. They also proposed two decomposition schemes to handle this formulation. Khachiyan et al. [2008] studied the most vital vertices/edges, and minimum vertex/edge blocker problems in the context of shortest path property. They showed that the most vital vertices/edges shortest path problem is NP-hard to approximate within a factor 2, and the minimum vertex/edge blocker version is NP-hard to approximate within a factor 1.36.

The most vital edges whose removal minimizes the weight of a minimum weighted cut in the graph is studied in Zenklusen [2014]. The author showed that there is a deterministic polynomial-time approximation scheme for this problem, and it can be solved efficiently when restricted to unit blocking costs.

Wollmer [1964] proposed an algorithm for solving the most vital edges maximum flow problem through a dual shortest path problem. A new integer programming model is developed for this problem in Wood [1993] along with valid inequalities to tighten the LP relaxation of the proposed model. The author showed that this problem is NP-complete even when restricted to unit blocking costs. First, a pseudo-polynomial algorithm that can solve non-trivial planar flow interdiction problems with multiple sources and sinks is presented in Zenklusen [2010b]. Proposed algorithm facilitates the possibility of removing vertices and edges both at the same time. Two classes of polynomially separable valid inequalities for the most vital edges maximum flow problem are presented in Altner et al. [2010]. They proved that the integrality gap of the linear programming relaxation of Wood [1993] is not bounded by a constant, even when strengthened by their proposed valid inequalities.

The most vital edges minimum spanning tree (MST) problem when each edge has a destruction cost, and a limited budget is available, was proved to be NP-hard in Lin and Chern [1993]. Later, Frederickson and Solis-Oba [1999] proved that this problem remains NP-hard even if the weights of edges are either 0 or 1, and the blocking cost is one unit. They presented an $O(\log k)$-approximation for this problem, where $k$ is the maximum number of edges allowed to be deleted. A mixed-integer linear programming formulation for this problem is also proposed by Bazgan et al. [2011b]. Bazgan et al. [2013b] proved that the most vital vertices MST problem is not approximable within a factor $n^{1-\epsilon}$, for any $\epsilon > 0$. They also showed that this problem is not 1.36 approximable even on graphs with weights 0 or 1. It was shown that the edge blocker version is NP-hard even on complete graphs with weights 0 or 1.

The most vital edges and minimum edge blocker assignment problems on complete bipartite graphs with $n$ vertices on each part are investigated by Bazgan et al. [2013c]. They proved that the most vital edges version is NP-hard to approximate within a factor of 2, and minimum edge blocker version is NP-hard to approximate within a factor of 1.36. They proposed an exact algorithm for both problems which can solve them in $O(n^{k+2})$ and $O(n^{n+1})$ time, respectively.

The most vital vertices median and maximal covering problems were first introduced and formulated as integer programming models in Church et al. [2004]. Later Bazgan et al. [2013a] proved that the most vital edges $p$-median
and $p$-center problems are NP-hard to approximate within a factor $\frac{7}{5} - \epsilon$ and $\frac{4}{3} - \epsilon$, respectively, for any $\epsilon > 0$. They also showed that the most vital vertices $p$-median/$p$-center problems are NP-hard to approximate within a factor $\frac{7}{5} - \epsilon$, for any $\epsilon > 0$. Additionally, they showed the complementary versions of these problems, minimum vertex/edge blocker $p$-median/$p$-center problems, are NP-hard to approximate within a factor 1.36.

Complexity of finding the most vital edges whose drop decreases the chromatic number by at least $d$ (a fixed number), is investigated on various classes of graphs in Bazgan et al. [2015]. They proved that this problem is NP-hard for any fixed $d \geq 1$ in general and complement of bipartite graphs. The most vital vertices independent set/vertex cover problems and their complementary forms, min vertex blocker independent set/vertex cover problems, are shown to be NP-hard on bipartite graphs and polynomial-time solvable on unweighted bipartite graphs, cographs, and graphs of bounded treewidth in Bazgan et al. [2011a]. The most vital non-edges whose adding decreases the cardinality of independent set by at least $d$, is NP-hard as well for any fixed $d \geq 1$ in general graphs (Bazgan et al., 2015).

Zenklusen et al. [2009] studied the complexity of the minimum edge blocker matching problem which is shown to be NP-complete on unweighted bipartite graphs. This problem can be solved in a polynomial time on grid graphs and trees (Ries et al., 2010). The most vital vertices/edges matching problems are proved to be weakly NP-hard on graphs consisting of isolated edges, and strongly NP-hard when all edge weights and interdiction costs are equal to one by Zenklusen [2010a]. Upon iterative rounding, he presented 4-approximation for the most vital edges matching problem when all edge weights are equal to one and 2-approximation on bipartite graphs, while he proved the most vital vertices matching problem is polynomial-time solvable on bipartite graph with unit edge weights and unit interdiction costs.

Minimum vertex blocker clique problem (VBCP) is studied in Mahdavi Pajouh et al. [2014], and they proved that its complexity is NP-hard on unweighted graphs. They presented linear 0-1 programming formulation with an exponential number of constraints. An analytical lower bound on the value of an optimal solution, and Facet-inducing inequalities are identified to develop the first exact algorithm by using a row generation approach. Becker [2015] presented an integer programming formulation, and developed a branch-and-cut algorithm to find the most vital vertices whose protection minimizes the maximum number of removed cliques. The most vital edges whose removal minimizes the size of a maximum clique in the remaining graph is studied by Tang et al. [2016] to evaluate their proposed exact, finitely convergent algorithms for solving bilevel min-max optimization problem when leader’s variables are binary.

A linear 0-1 programming formulation for the minimum edge blocker dominating set problem (EBDP) is presented in Mahdavi Pajouh et al. [2015]. They proved that this problem is NP-hard and identified an analytical lower bound for the value of an optimal solution, and facet-inducing inequalities to develop the first exact algorithm for solving EBDP by utilizing branch-and-cut approach.
1.1 Problem description and motivation

In this study, we consider the minimum cost vertex blocker clique problem, which is an extension of Mahdavi Pajouh et al. [2014]. By assigning a weight and a cost to each vertex, a generalized form of the minimum vertex blocker clique problem (VBCP) is considered in which weight and cost can be interpreted as the "importance" and "blocking resistance" of the vertex, respectively.

Given a simple undirected graph \( G = (V, E) \) with weights and costs on its vertices, let \( V = \{1, 2, \ldots, n\} \) and vectors \( w = [w_i \in \mathbb{Q}] \) and \( c = [c_i \in \mathbb{Q}] \) represent the weights and costs of all vertices \( i \in V \), respectively. Given a set \( S \subseteq V \), let \( W(S) = \sum_{i \in S} w_i \) and \( C(S) = \sum_{i \in S} c_i \). The subgraph induced by a set \( S \subseteq V \) is denoted by \( G[S] = (S, E \cap (S \times S)) \). A clique is a subset of vertices that induces a complete subgraph. Maximum weighted clique in \( G \) is a clique \( D \subseteq V \) such that \( W(D) \) is maximum and its weight with respect to \( w \) is denoted by \( \omega_w^G \). Given \( r > 0 \), the minimum cost vertex blocker clique problem (CVBCP) is to find a set of vertices \( S \subseteq V \) such that \( \omega_w^G[V \setminus S] \leq r \) and \( C(S) \) is minimum.

Cost-efficient vertex interdiction is important from both defender and attacker perspectives in order to find the vertices playing important roles in preserving a particular property of the network. In our case, weight of the maximum weighted clique in the remaining graph is the desired property as it enables effective communication between important components of the network. Identifying these critical vertices would be an important step to preserve this effective communication among important actors inside the network.

1.2 Contributions

In this study, a new characterization of the set of feasible solutions to CVBCP is proposed, which results a new linear 0-1 programming formulation involving an exponential number of constraints. The proposed formulation is then solved by a branch-and-cut algorithm in a lazy fashion. Since CVCPB is NP-hard, we also propose new combinatorial bounding schemes, and employ them to develop the first combinatorial branch and bound algorithm for this problem. The computational performance of these two exact algorithms is studied on a test-bed of randomly generated graphs, DIMACS instances and real-life graphs.

2 References

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Fixed Costs and Shared Resources Allocation in Two-stage Network DEA

Abstract: Data envelopment analysis (DEA) is an approach for performance evaluation and benchmarking. In many real managerial decisions, fixed costs are used in building common facilities used by an entire organization, and need to be shared by sub-components in decision-making units (DMUs). The current paper discusses the problem of fixed cost allocation when DMUs are composed of two linked stages. We develop a set of DEA models to measure the performance by treating fixed cost as an additional input factor shared in two stages among a set of DMUs. We propose three procedures based on different objectives in reality to obtain a fair cost allocation plan. The models are developed under the assumption when the DEA best-practice is of the constant returns to scale (CRS), but can be readily applied under the assumption of the variable return to scale (VRS). The proposed models are illustrated using an existing data set of Information Technology (IT) Investment.

Keywords: Two-stage DEA network; Efficiency; Fixed cost allocation; Shared inputs in both stages
1 Introduction

Data envelopment analysis (DEA) is an approach for measuring relative performance and benchmarking of a homogeneous set of decision-making units (DMUs) with multiple inputs and outputs (Charnes et al., 1978). As discussed in many DEA studies, DMUs can have two-stage structures where in addition to the inputs and outputs, a set of intermediate measures exist in-between the two stages. These intermediate measures can be regarded as the outputs from the first stage that become the inputs to the second stage. Kao and Hwang (2008) study the two-stage DEA to examine the operation of the non-life insurance industry in Taiwan. In their study, the first stage is characterized by marketing of the insurance, where clients are attracted to pay direct written premiums and reinsurance premiums are received from other insurance companies. The second stage is characterized by investment, where premiums are invested in a portfolio to earn profits. In many real world cases, inputs to the first stage are actually also shared by the second stage. Seiford and Zhu (2000) divide the commercial bank’s production process into the stages of profitability and marketability. In the stage of profitability, labor and assets are regarded as inputs, while profits and revenue are regarded as outputs. The second stage of marketability is measured using profits and revenue as inputs, and the outputs are market value, returns and earning per share. Notice in this example, labor and assets are actually shared inputs for two stages.

In the DEA literature, DEA methods have been applied to fixed cost. Fixed cost allocation method base on DEA can be divided into efficiency invariant model and efficiency variant model. Cook and Kress (1999) use the DEA method to solve the problem of fixed cost and treated fixed cost as a new input of a decision-making factor, which follows efficiency value invariance and Pareto minimization. Beasley (2003) builds a model by maximizing the average efficiency value of the whole organization to allocate the fixed cost. Du et al. (2014), on the other hand, utilize cross efficiency to distribute the fixed cost and shared resources among DMUs. They also believe that the efficiency value of every DMU fixed cost after allocation should be larger than the original CCR efficiency value. A unique fixed cost allocation plan is obtained after final calculation through a continuous iterative process. Li et al. (2013) and Si et al. (2013) treat the fixed cost as a new input. They define an integration of fixed cost allocation plan as a collection of fixed cost allocation plan.
Above research is based on standard DEA and does not consider DMUs’ internal structure. This current paper treats fixed cost as an additional input shared in two stages with respect to a two-stage network DEA method. The resulting model may generate numerous fixed cost allocation plans. Therefore, secondary goals are introduced via three different procedures. The rest of this study is organized as follows. Section 2 develops models for measuring the overall efficiency of DMUs. Section 3 and Section 4 use a secondary process to obtain allocation plan via different procedures in two situations, respectively. Section 5 applies a data set to priori models. Section 6 presents the conclusions and directions for future research.

2. A two-stage network DEA model with fixed cost allocation

Figure 1 shows a two-stage network structure where some inputs are shared by the two stages, some outputs from stage 1 do not become inputs to the second stage, and second stage has its own inputs. Suppose that there is a set of n DMUs denoted by $DMU_j (j = 1,2,...,n)$ and each $DMU_j$ has m inputs denoted by $x_i (i = 1,2,...,m)$ to the whole process. We denote inputs which are the only inputs to the first stage as $x_{i,j}(i_1 \in I_1)$, inputs which are shared in the two stages as $x_{i,j}(i_2 \in I_2 \cup I_2 \cup i = 1,2,...,m)$, and inputs which are the only inputs to the second stage as $x_{i,j}(i_3 \in I_3)$. Input $x_{i,j}(i_2 \in I_2)$ is shared by both stages, where $\alpha x_{i,j}(i_2 \in I_2)$ is in the first stage and $(1-\alpha x_{i,j}(i_2 \in I_2)$ is in the second stage. Suppose also that each $DMU_j (j = 1,2,...,n)$ has D outputs denoted by $Z_{d,j}(d = 1,2,...,D)$ from the first stage. $\beta D_{d,j}(d = 1,2,...,D)$ is part of outputs from the first stage and used as a input in second stage, while the rest part is one of the final outputs, denoted as $(1-\beta D_{d})Z_{d,j},d = 1,2,...,D$. $Y_{r}(r = 1,...,s)$ are the outputs from the second stage.

In our paper, we regard fixed cost allocation as an input factor of each DMU, and our figure is similar to the two-stage structures studied in Chen et al. (2010). Figure 2 illustrates formation of inputs and outputs of our two-stage network structure with fixed cost allocation. We denote R as a total fixed cost of all DMUs. $\eta R$ stands for the total fixed
cost allocated in the first stage, while \((1 - \eta)R\) stands for the total fixed cost allocated in the second stage. \(r_j^1 (j = 1, 2, ..., n)\) and \(r_j^2 (j = 1, 2, ..., n)\) are the fixed cost shared by both stages respectively for each DMU. For example, \(r_j^1\) stands for the fixed cost allocated to the first DMU in the first stage, and then \(\sum_{j=1}^{n} r_j^1\) equals \(\eta R\) (total fixed cost allocated in the first stage for all DMUs). Similar to Chen et al. (2010), the value of \(\alpha_{ij}\) and \(\beta_d\) should be within a certain range, which can be determined by the user/decision maker. \(\eta\) is a parameter between [0,1], representing the proportion of the total cost being allocated to the first stage.

For each \(DMU_o\) under the assumption of constant returns to scale (CRS), the efficiency value of \(DMU_o\) at the first and second stages can be calculated by models (1) and (2), respectively

\[
e^1_o = \max \frac{\sum_{d=1}^{D} w_d^o Z_{do}}{\sum_{i \in I_1} v_{i1}^o X_{i1} + \sum_{i \in I_2} v_{i2}^o \alpha_{i2} X_{i2} + r_j^1}
\]

s.t.

\[
\sum_{i \in I_1} v_{i1}^o X_{i1} + \sum_{i \in I_2} v_{i2}^o \alpha_{i2} X_{i2} + r_j^1 \leq 1, \forall j
\]

\[
L_{ij} \leq \alpha_{ij} \leq U_{ij}, i \in I_1, j \leq I_2, \forall j
\]

\[
\sum_{j=1}^{n} r_j^1 = \eta R
\]

\[
L^R \leq \eta \leq U^R, 0 < L^R \leq U^R < 1
\]

(1)

\[
e^2_o = \max \frac{\sum_{r=1}^{s} u_r^o Y_{r0}}{\sum_{i \in I_1} v_{i1}^o X_{i1} + \sum_{i \in I_2} v_{i2}^o (1 - \alpha_{i2}) X_{i2} + \sum_{d=1}^{D} w_d^o \beta_{do} Z_{do} + r_j^2}
\]

s.t.

\[
\sum_{r=1}^{s} u_r^o Y_{r0} \leq 1, \forall j
\]

\[
\sum_{i \in I_1} v_{i1}^o X_{i1} + \sum_{i \in I_2} v_{i2}^o (1 - \alpha_{i2}) X_{i2} + \sum_{d=1}^{D} w_d^o \beta_{do} Z_{do} + r_j^2 \leq 1, \forall j
\]

\[
L_{ij} \leq \alpha_{ij} \leq U_{ij}, i \in I_1, j \leq I_2, \forall j
\]

\[
L_{dj} \leq \beta_{dj} \leq U_{dj}, d = 1, ..., D, \forall j
\]

\[
\sum_{j=1}^{n} r_j^2 = (1 - \eta)R
\]

\[
L^R \leq \eta \leq U^R, 0 < L^R \leq U^R < 1
\]

(2)
Similar to Beasley (2003), the weight $r^j_1$ and $r^j_2$ are set as 1. Similar to Chen et al. (2010), the $DMU_o$’s overall efficiency value is the weighted average of efficiency at two stages, as showed in (3)

$$e_o = e^1_o + e^2_o$$ (3)

where $\omega_1 + \omega_2 = 1$, $\omega_1$ and $\omega_2$ represent the importance degree at each stage and can be by the following formula (4) and formula (5), respectively.

$$\omega_1 = \frac{\sum_{i: x_i \in I} v^o_{i1} X_{kj} + \sum_{i: x_i \in I} v^o_{i2} + \sum_{i: x_i \in I} v^o_{i3} \alpha_{ij} X_{kj} + r^j_1}{\sum_{i: x_i \in I} v^o_{i1} X_{kj} + \sum_{i: x_i \in I} v^o_{i2} + \sum_{i: x_i \in I} v^o_{i3} \alpha_{ij} X_{kj} + \sum_{d=1}^D w^o_{d} \beta_{dj} Z_{dj} + r^j_1 + r^j_2}$$ (4)

$$\omega_2 = \frac{\sum_{i: x_i \in I} v^o_{i1} X_{kj} + \sum_{i: x_i \in I} v^o_{i2} + \sum_{i: x_i \in I} v^o_{i3} \alpha_{ij} X_{kj} + \sum_{d=1}^D w^o_{d} \beta_{dj} Z_{dj} + r^j_1 + r^j_2}{\sum_{i: x_i \in I} v^o_{i1} X_{kj} + \sum_{i: x_i \in I} v^o_{i2} + \sum_{i: x_i \in I} v^o_{i3} \alpha_{ij} X_{kj} + \sum_{d=1}^D w^o_{d} \beta_{dj} Z_{dj} + r^j_1 + r^j_2}$$ (5)

Then the overall efficiency value can be calculated in the following model (6)
By applying Charnes-Cooper (1962) transformation, we let

$$
\tau = \frac{1}{\sum_{i \in \mathcal{I}} v^o_{i_1} X_{i_1} + \sum_{i \in \mathcal{I}_2} v^o_{i_2} X_{i_2} + \sum_{i \in \mathcal{I}_3} v^o_{i_3} X_{i_3} + \sum_{d \in \mathcal{D}} w^o_d \beta_d Z_{d_o} + r^1 + r^2}, \quad w^O_d = w^o_d,
$$

$$
u^O_i = u^o_{i_1}, \quad v^O_{i_2} = v^o_{i_2}, \quad \text{and} \quad v^O_{i_3} = v^o_{i_3},$$

and then model (6) can be converted to the following model (7).

$$
e^o_i = \max \sum_{d \in \mathcal{D}} w^O_d Z_{d_o} + \sum_{d \in \mathcal{D}} u^O_i Y_{d_o}$$

s.t.

$$\sum_{d \in \mathcal{D}} w^O_d Z_{d_o} - \left( \sum_{i \in \mathcal{I}_1} v^O_{i_1} X_{i_1} + \sum_{i \in \mathcal{I}_2} v^O_{i_2} X_{i_2} + \sum_{i \in \mathcal{I}_3} v^O_{i_3} X_{i_3} + \sum_{d \in \mathcal{D}} w^O_d \beta_d Z_{d_o} + r^1 + r^2 \right) \leq 0, \forall j$$

$$\sum_{d \in \mathcal{D}} u^O_i Y_{d_o} - \left( \sum_{i \in \mathcal{I}_1} v^O_{i_1} X_{i_1} + \sum_{i \in \mathcal{I}_2} v^O_{i_2} X_{i_2} + \sum_{i \in \mathcal{I}_3} v^O_{i_3} X_{i_3} + \sum_{d \in \mathcal{D}} w^O_d \beta_d Z_{d_o} + r^1 + r^2 \right) \leq 0, \forall j$$

$$\sum_{d \in \mathcal{D}} w^O_d Z_{d_o} + \sum_{d \in \mathcal{D}} u^O_i Y_{d_o} - \left( \sum_{i \in \mathcal{I}_1} v^O_{i_1} X_{i_1} + \sum_{i \in \mathcal{I}_2} v^O_{i_2} X_{i_2} + \sum_{i \in \mathcal{I}_3} v^O_{i_3} X_{i_3} + \sum_{d \in \mathcal{D}} w^O_d \beta_d Z_{d_o} + r^1 + r^2 \right) \leq 0, \forall j$$

$$L_{i,j} \leq \alpha_{i,j} \leq U_{i,j}, \quad \forall i, j \in \mathcal{I} \text{ s.t.} \quad L_{i,j} \leq \beta_{d,j} \leq U_{d,j}, \quad d = 1, \ldots, D, \forall j$$

$$\sum_{j \in \mathcal{J}_1} r^1_j = \eta R$$

$$\sum_{j \in \mathcal{J}_2} r^2_j = \tau (1 - \eta) R$$

$$L^E \leq \eta \leq U^E, \quad 0 < L^E \leq U^E < 1$$

(7)
Notice that model (7) is a non-linear model because of \( \sum_{i} v_i^o \alpha_{i,j} X_{i,j} \) and \( \sum_{d} w_d^o \beta_{d,j} Z_{d,j} \). To convert it into a linear model, we let \( A_{i,j} = v_i^o \alpha_{i,j} \), \( B_{d,j} = w_d^o \beta_{d,j} \), \( t^j_1 = \tau \ast r^j_1 \), \( t^j_2 = \tau \ast r^j_2 \), \( \eta' = \tau \ast \eta \) and \( \delta = \tau - \eta' \). The above model (7) could be transformed as the following model (8),

\[
e^* = \max \sum_{d} w_d^o Z_{d,o} + \sum_{i} u_i^o Y_{i,o}
\]

Subject to:

\[
\sum_{d} w_d^o Z_{d,j} - \left( \sum_{i} v_i^o X_{i,j} + \sum_{j} A_{i,j} X_{i,j} + t^j_2 \right) \leq 0, \forall j
\]

\[
\sum_{j} u_j^o Y_{j,o} - \left( \sum_{i} v_i^o X_{i,j} + \sum_{j} B_{d,j} Z_{d,j} + t^j_2 \right) \leq 0, \forall j
\]

\[
\sum_{j} u_j^o Y_{j,o} - \left( \sum_{i} v_i^o X_{i,j} + \sum_{j} B_{d,j} Z_{d,j} + t^j_2 + t^j_1 \right) \leq 0, \forall j
\]

\[
\sum_{i} v_i^o X_{i,o} + \sum_{j} B_{d,j} Z_{d,o} + t^j_2 + t^j_1 = 1
\]

\[
L_{i,j} v_i^o \leq A_{i,j} \leq U_{i,j} v_i^o, i,j \in I, \forall j
\]

\[
L_{d,j} w_d^o \leq B_{d,j} \leq U_{d,j} w_d^o, d = 1,...,D, \forall j
\]

\[
\sum_{j} t^j_2 = \eta^* R
\]

\[
\sum_{j} t^j_1 = \delta R
\]

\[
\tau L^\delta \leq \eta' \leq \tau U^\delta, 0 < U^\delta \leq U^R < 1, \tau (1 - U^\delta) \leq \delta \leq \tau (1 - L^\delta)
\]

(8)

However, during conversation, if lower bound of \( \alpha_{i,j} \) and \( \beta_{d,j} \) is not zero, the value of \( v_i^o \) and \( w_d^o \) must be positive, which directly causes \( A_{i,j} \) and \( B_{d,j} \) must positive. In order to solve this problem, we consider the following two situations,

**Situation 1**: the lower bound of the value range of \( \alpha_{i,j} \) and \( \beta_{d,j} \) are zero.

**Situation 2**: the lower bound of the value range of \( \alpha_{i,j} \) and \( \beta_{d,j} \) are larger than zero.

If \( \alpha_{i,j} \) and \( \beta_{d,j} \)'s lower bound of value range are zero, we use model (8). Otherwise, we add a constraint formula (8-a) to model (8).

\[
v_i^o, w_d^o > 0, i_t, d = 1,...,D \quad (8-a)
\]
According to Li et al. (2013), it is possible that some sets of common weights are zero, and some of them are positive. Therefore, when \( \alpha_{i,j} \) and \( \beta_{d,j} \) is not zero, it cannot be guaranteed that there must exist a set of common weights which makes all \( DMU_j \) as (weak) decision unit with the constraint \( v^0_{i_2}, w^0_d > 0, i_2 \in I_2, d = 1, ..., D \). However, under most circumstances, at least one set of common weights which larger than zero makes all \( DMU_j \) as (weak) decision units.

**Theorem 1:** When the lower bounds of \( \alpha_{i,j} \) and \( \beta_{d,j} \) are zero, there at least exists a set of common weights that makes the overall efficiency value of all \( DMU_j \) equals to one. Namely, some allocation plans can make all \( DMU_j \) efficient.

The proof of theorem 1 is similar to that in Li et al. (2013).

### 3 Allocation analyses under situation 1

According to Theorem 1, when the lower bounds of \( \alpha_{i,j} \) and \( \beta_{d,j} \) are zero, at least one set of common weights makes the overall efficiency value equal to 1. Then we can decide how to allocate fixed cost and shared inputs by using model (9).  

\[
\begin{align*}
    r^1_j &= \sum_{d=1}^{D} w^0_d Z_d - \left( \sum_{i_1 \in I_1} v^0_{i_1} X_{i_1} + \sum_{i_2 \in I_2} A_{i_2,j} X_{i_2,j} \right), \forall j \\
    r^2_j &= \sum_{r=1}^{s} u^0_r Y_j - \left( \sum_{i_1 \in I_1} v^0_{i_1} X_{i_1} + \sum_{i_2 \in I_2} (v^0 - A_{i_2,j}) X_{i_2,j} + \sum_{d=1}^{D} B_{d,j} Z_{d,j} \right), \forall j \\
    L_{i_2,j} v^0_{i_1} &\leq A_{i_2,j} \leq U_{i_1,j} v^0_{i_1}, i_2 \in I_2, \forall j \\
    L_{d,j} w^0_d &\leq B_{d,j} \leq U_{d,j} w^0_d, d = 1, ..., D, \forall j \\
    \sum_{j=1}^{n} r^1_j &= \eta R \\
    \sum_{j=1}^{n} r^2_j &= (1-\eta) R \\
    L^R &\leq \eta \leq U^R, 0 < L^R \leq U^R < 1
\end{align*}
\]  

(9)
As the allocation plan is not unique by using model (9), further allocation criteria are needed. This paper develops three different allocation procedures to impose secondary goals.

**Procedure 1: Minimum satisfaction maximization**

At the beginning, we sum the maximum allocation value and the minimum allocation value for each DMU by using model (10-a) and model (10-b) respectively.

\[
\max \quad (r^1 + r^2)
\]

s.t.

\[
r_j^1 = \sum_{d=1}^n w^d \rho_{d,j} - \left( \sum_{i \in I} \rho_{i,j} x_{i,j} + \sum_{i \in I} \rho_{i,j} x_{i,j} \right), \forall j
\]

\[
r_j^2 = \sum_{r=1}^m u^r \varsigma_{r,j} - \left( \sum_{i \in I} \varsigma_{i,j} x_{i,j} + \sum_{i \in I} \varsigma_{i,j} (\rho_{i,j} - \rho_{i,j}) x_{i,j} + \sum_{d=1}^n B_{d,j} \right), \forall j
\]

\[
L_{i,j} \rho_{i,j} \leq A_{i,j} \leq U_{i,j} \rho_{i,j}, i_2 \in I_2, \forall j
\]

\[
L_{d,j} \rho_{d,j} \leq B_{d,j} \leq U_{d,j} \rho_{d,j}, d = 1, ..., D, \forall j
\]

\[
\sum_{j=1}^n r_j^1 = \eta R
\]

\[
\sum_{j=1}^n r_j^2 = (1 - \eta) R
\]

\[
L^R \leq \eta \leq U^R, 0 < L^R \leq U^R < 1
\]

\[(10-a)\]
$$\min \ (r_j^1 + r_j^2)$$

s.t.

$$r_j^1 = \sum_{d=1}^{D} w_d^0 Z_{dj} - \left( \sum_{i \in t_1} v_i^0 X_{ij} + \sum_{i \in t_2} A_{ij} X_{ij} \right), \forall j$$

$$r_j^2 = \sum_{i \in t_1} v_i^0 Y_{ij} - \left( \sum_{i \in t_1} v_i^0 X_{ij} + \sum_{i \in t_2} (v_i^0 - A_{ij}) X_{ij} + \sum_{d=1}^{D} B_{dj} Z_{dj} \right), \forall j$$

$$L_{i,j}^0 \leq A_{i,j} \leq U_{i,j} \nu_{i,j}^0, i_2 \in I_2, \forall j$$

$$L_d w_d^0 \leq B_{dj} \leq U_d w_d^0, d = 1, ..., D, \forall j$$

$$\sum_{j=1}^{n} r_j^1 = \eta R$$

$$\sum_{j=1}^{n} r_j^2 = (1-\eta)R$$

$$L^R \leq \eta \leq U^R, 0 < L^R \leq U^R < 1$$

(10 – b)

Where $r_j^1$, $r_j^2$ represent the allocation values in the first stage and in the second stage, respectively. The DMU allocation value $(r_j^1 + r_j^2)$ ranges from $(r_0^1 + r_0^2)$ to $(r_0^1 + r_0^3)$. For each DMU, it would like to choose $(r_j^1 + r_j^2)$ rather than $(r_j^1 + r_j^3)$. However, if all DMUs select $(r_j^1 + r_j^3)$, the fixed cost is not allocated fully, namely $\sum_{j=1}^{n} (r_j^1 + r_j^3) < R$. 

$$\rho_0 = \frac{(r_0^1 + r_0^3)}{(r_0^1 + r_0^2)} \frac{(r_0^1 + r_0^3)}{(r_0^1 + r_0^2)}$$ (11)

Definition 1: $\rho_0$ is the satisfaction of fixed cost and inputs allocation for each DMU, as showed in model (11)

If $(r_j^1 + r_j^3)$ is closer to $(r_j^1 + r_j^2)$, the DMU is more willing to select the plan.

Otherwise, if $(r_j^1 + r_j^3)$ is closer to $(r_j^1 + r_j^3)$, the DMU is less willing to choose the plan.

In model (11), when $(r_j^1 + r_j^3) = (r_0^1 + r_0^3)$, $\rho_0$ equals 1, representing the most satisfied plan. As $\sum_{j=1}^{n} (r_j^1 + r_j^3) < R$, $\rho_0$ will not reach maximum value at the same time. So we
can obtain a unique fixed cost and inputs allocation through maximizing the minimum satisfaction defined in (11), as shown in model (12).

\[
\max \quad \delta \\
\text{s.t.}
\]

\[
r_j^1 = \sum_{d=1}^{n} w_j^O Z_{dj} - \left( \sum_{h \in l_i} v_h^O X_{i,h,j} + \sum_{l_2 \in l_{i}} A_{i,j} X_{i,j} \right), \forall j
\]

\[
r_j^2 = \sum_{r=1}^{R} u_r^O Y_{r,j} - \left( \sum_{l_1 \in l_2} v_{l_1}^O X_{i,l_1,j} + \sum_{l_2 \in l_{i}} (v_{l_2}^O - A_{i,j}) X_{i,j} + \sum_{d=1}^{n} B_{d,j} Z_{dj} \right), \forall j
\]

\[
L_{i,j} v_{l_1}^O \leq A_{i,j} \leq U_{i,j} v_{l_2}^O, l_1, l_2 \in I_2, \forall j
\]

\[
L_{d,j} w_{d,j}^O \leq B_{d,j} \leq U_{d,j} w_{d,j}^O, d = 1, ..., D, \forall j
\]

\[
\sum_{j=1}^{n} r_j^1 = \eta R
\]

\[
\sum_{j=1}^{n} r_j^2 = (1-\eta)R
\]

\[
L^R \leq \eta \leq U^R, 0 < L^R \leq U^R < 1
\]

\[
\rho_j = \frac{(r_j^1 + r_j^2)}{(r_j^1 + r_j^2)} - \frac{(r_j^1 + r_j^2)}{\sum_{j=1}^{n} (r_j^1 + r_j^2)} \geq \delta, \forall j
\]

Procedure 2: Minimum the distance of satisfaction with desirable results and undesirable results

This procedure is based on TOPSIS ( Technique for Order Preference by Similarity to Ideal Solution). First, we calculate possible maximum satisfaction value and possible minimum satisfaction value according to model (13-a) and model (13-b), respectively. All maximum results of DMUs are a set of desirable solutions as shown in model (14) and all minimum results of DMUs are a set of undesirable solutions as shown in model (15).
\[
\text{max} \quad \rho(O)
\]
\[
\text{s.t.} \\
\quad r_j^1 = \sum_{d=1}^{D} w_d^0 Z_d - \left( \sum_{i \in I} y_i X_i^0 + \sum_{i \in I} A_{ij} X_{ij} \right), \forall j
\]
\[
\quad r_j^2 = \sum_{d=1}^{D} u_d^0 Y_d - \left( \sum_{i \in I} y_i X_i^0 + \sum_{i \in I} \left( v_i - A_{ij} \right) X_{ij} + \sum_{d=1}^{D} B_{ij} Z_d \right), \forall j
\]
\[
\quad L_{i_2} y_{i_2}^0 \leq A_{i_2 j} \leq U_{i_2} y_{i_2}^0, i_2 \in I_2, \forall j
\]
\[
\quad L_{d_2} w_{d_2}^0 \leq B_{d_2 j} \leq U_{d_2} w_{d_2}^0, d = 1, \ldots, D, \forall j
\]
\[
\quad \sum_{j=1}^{n} r_j^1 = \eta R
\]
\[
\quad \sum_{j=1}^{n} r_j^2 = (1-\eta)R
\]
\[
\quad L^R \leq \eta \leq U^R, 0 < L^R \leq U^R < 1
\]
\[
\quad \rho_j = \frac{\overline{r}_j^1 - \overline{r}_j^2}{\overline{r}_j^1 + \overline{r}_j^2}, \forall j
\]
\[
\quad (13-a)
\]
\[
\text{min} \quad \rho(O)
\]
\[
\text{s.t.} \\
\quad r_j^1 = \sum_{d=1}^{D} w_d^0 Z_d - \left( \sum_{i \in I} y_i X_i^0 + \sum_{i \in I} A_{ij} X_{ij} \right), \forall j
\]
\[
\quad r_j^2 = \sum_{d=1}^{D} u_d^0 Y_d - \left( \sum_{i \in I} y_i X_i^0 + \sum_{i \in I} \left( v_i - A_{ij} \right) X_{ij} + \sum_{d=1}^{D} B_{ij} Z_d \right), \forall j
\]
\[
\quad L_{i_2} y_{i_2}^0 \leq A_{i_2 j} \leq U_{i_2} y_{i_2}^0, i_2 \in I_2, \forall j
\]
\[
\quad L_{d_2} w_{d_2}^0 \leq B_{d_2 j} \leq U_{d_2} w_{d_2}^0, d = 1, \ldots, D, \forall j
\]
\[
\quad \sum_{j=1}^{n} r_j^1 = \eta R
\]
\[
\quad \sum_{j=1}^{n} r_j^2 = (1-\eta)R
\]
\[
\quad L^R \leq \eta \leq U^R, 0 < L^R \leq U^R < 1
\]
\[
\quad \rho_j = \frac{\overline{r}_j^1 - \overline{r}_j^2}{\overline{r}_j^1 + \overline{r}_j^2}, \forall j
\]
\[
\quad (13-b)
\]
\[
D^* = (\rho_1^{\text{max}}, \rho_2^{\text{max}}, \ldots, \rho_n^{\text{max}}) \quad (14)
\]
\[ D^- = (\rho_1^{\text{min}}, \rho_2^{\text{min}}, ..., \rho_3^{\text{min}}) \quad (15) \]

Then, we calculate the distance from actual satisfaction to desirable solutions, and the distance from actual satisfaction to undesirable solutions. A rational objective is to minimize the distance between satisfaction and desirable solutions, at the same time, to maximize the distance between satisfaction and undesirable solutions. Therefore, we can obtain a unique allocation plan by minimizing the distance of satisfaction from desirable results to undesirable results, as shown in model (16).

\[ \min \sum_{O=1}^{n} \left[ (O)^{\text{max}} - (O) - (O)^{\text{min}} \right] \]

s.t.
\[
\begin{align*}
  r_j^1 &= \sum_{d=1}^{D} w_d^O Z_{dj} \left( \sum_{i_1 \in I_1} v_{i_1}^O X_{i_1 j} + \sum_{i_2 \in I_2} A_{i_2 j} X_{i_2 j} \right), \quad j \\
  r_j^2 &= \sum_{r=1}^{r} u_r^O Y_{rj} \left( \sum_{i_1 \in I_1} v_{i_1}^O X_{i_1 j} + \sum_{i_2 \in I_2} (v_{i_2}^O - A_{i_2 j}) X_{i_2 j} + \sum_{d=1}^{D} B_d^O Z_{dj} \right), \quad j \\
  L_{t_1,j} v_{i_1}^O &\leq A_{i_2 j} \leq U_{t_2,j} v_{i_2}^O, \quad i_1, i_2 \in I_2, \quad j \\
  L_{d,j} w_d^O &\leq B_{d,j} \leq U_{d,j} w_d^O, \quad d = 1, ..., D, \quad j \\
  \sum_{j=1}^{n} r_j^1 &= R \\
  \sum_{j=1}^{n} r_j^2 &= (1 - h)R \\
  L^R &\leq U^R, \quad 0 < L^R \leq U^R < 1 \\
  j &= \frac{(r_j^1 + r_j^2)}{(r_j^1 + r_j^2)}, \quad j
\]

(16)

**Procedure 3:** Minimum similarity maximization

The similarity is defined by TOPSIS algorithm. Based on this theory, we can obtain a unique allocation plan by maximizing the minimum similarity scale.

\[ Q_0 = \frac{\rho_0}{\rho_0^* + \rho_0^{-}} \quad (17) \]

Definition 2: \( Q_0 \) is the similarity of \( DMU_0 \) when allocates fixed cost and inputs, as shown in model (17).
Procedure 3 is a rational way to allocate fixed cost and resources, as shown in model (18).

$$\max \varphi$$

s.t.

$$r^1_j = \sum_{i=1}^m w^0_i z_{ij} - \left( \sum_{i \in i_1} v^0_i X_{ij} + \sum_{i \in i_2} A_{ij} x_{ij} \right), \forall j$$

$$r^2_j = \sum_{i=1}^m u^0_i y_j - \left( \sum_{i \in i_3} v^0_i X_{ij} + \sum_{i \in i_2} (v^0_i - A_{ij}) X_{ij} + \sum_{d=1}^n B_{ij} z_{ij} \right), \forall j$$

$$L_{i_3j}, v^0_i \leq A_{ij}, v^0_i, i_3 \in I_3, \forall j$$

$$L_{dij} w^0_d \leq B_{ij} \leq U_{dij} w^0_d, d = 1, ..., D, \forall j$$

$$\sum_{j=1}^n r^1_j = \eta R$$

$$\sum_{j=1}^n r^2_j = (1-\eta)R$$

$$L^R \leq \eta \leq U^R, 0 < L^R \leq U^R < 1$$

$$\rho_j = \frac{(r^1_j + r^2_j) - (r^1_j + r^2_j)}{(r^1_j + r^2_j) - (r^1_j + r^2_j)}, \forall j$$

$$\rho^i_j = \rho_j - \rho^i_j$$

$$\rho_j^i = \rho_j - \rho_j^i$$

$$Q_j = \frac{\rho^i_j}{\rho_j^i + \rho_j} \geq \varphi, \forall J$$

(18)

4 Allocation analysis under situation 2

When the lower bounds of $\alpha_{ij}$ and $\beta_{ij}$ are not zero, we should guarantee all weights are greater than zero by adding formula (8-a) to model (8) so that at least one set of common weights makes the overall efficiency be one. Thus, when the lower bounds of $\alpha_{ij}$ and $\beta_{ij}$ are not zero, we consider the following two cases.

**Case 1:** there exists at least one common set of weights which makes the overall efficiency be one.

**Case 2:** there is not any common set of weights which makes the overall efficiency be one.
In order to distinguish case 1 and case 2, we add (8-a) to model (10) and calculate minimum/maximum \((r^1_j + r^2_j)\) for any \(DMU_j\). If there is a feasible solution, it is the case 1, otherwise.

In case 1, fixed cost and inputs allocation procedure are same as the procedure under situation 1. The only thing we need to notice is that we should remember to add (8-a) when we calculate each process in order to guarantee a common set of weights greater than zero.

In case 2, it does not exist any common set of weights making the overall efficiency be one. An organization always hopes to maximize the sum of the overall efficiency of all branches rather than focusing on one of the branch’s efficiency. And the overall efficiency is at least larger than the overall efficiency before allocating the cost. So we can use the following steps to obtain a unique allocation plan. First, we calculate an the pre-allocating overall efficiency \(e^*_o\) by using model (6) for each DMU. Second, we calculate the efficiency of each DMU \(e^*_j\) respectively under guaranteeing the \(e^*_o\) of \(DMU_o\). For each \(DMU_j\), model (19) is solved \(n\) times. Third, Then a unique allocation plan is the calculation of \(DMU_o\) by use model (19) where \(o = \max \left\{o \mid e(o, j) = \sum_{j=1}^{n} e^*_j\right\}\).
\[
\begin{align*}
\text{max} & \quad e_j^O = \sum_{d=1}^{D} w_d^O \cdot Z_{d,j} + \sum_{r=1}^{s} u_r^O \cdot Y_{r,j} \\
\text{s.t.} & \quad \sum_{d=1}^{D} w_d^O Z_{d,j} - \left(\sum_{i=1}^{I_1} v_{i,j}^O X_{i,j} + \sum_{i=1}^{I_2} A_{i,j} X_{i,j} + t_j^I\right) \leq 0, \forall j \\
& \quad \sum_{r=1}^{s} u_r^O Y_{r,j} - \left(\sum_{i=1}^{I_1} v_{i,j}^O X_{i,j} + \sum_{i=1}^{I_2} (v_d^O - A_{i,j}) X_{i,j} + \sum_{d=1}^{D} B_{d,j} Z_{d,j} + t_j^O\right) \leq 0, \forall j \\
& \quad \sum_{d=1}^{D} w_d^O Z_{d,j} + \sum_{r=1}^{s} u_r^O Y_{r,j} - \left(\sum_{i=1}^{I_1} v_{i,j}^O X_{i,j} + \sum_{i=1}^{I_2} v_0^O X_{i,j} + \sum_{i=1}^{I_1} v_{i,j}^O X_{i,j} + \sum_{d=1}^{D} B_{d,j} Z_{d,j} + t_j^I + t_j^O\right) \leq 0, \forall j \\
& \quad \sum_{i=1}^{I_1} v_{i,j}^O X_{i,j} + \sum_{i=1}^{I_2} v_0^O X_{i,j} + \sum_{i=1}^{I_1} v_{i,j}^O X_{i,j} + \sum_{d=1}^{D} B_{d,j} Z_{d,j} + t_j^I + t_j^O = 1 \\
L_{i,j}^O \quad & \leq A_{i,j} \leq U_{i,j} v_{i,j}^O, I_2 \subseteq I_2, \forall j \\
L_{d,j}^O \quad & \leq B_{d,j} \leq U_{d,j} w_d^O, d = 1, \ldots, D, \forall j \\
\sum_{j=1}^{n} t_j^I & = \eta R \\
\sum_{j=1}^{n} t_j^O & = \delta R \\
\tau L^R \leq \eta \leq \tau U^R, 0 < U^R \leq U^R < 1, \tau(1 - U^R) \leq \delta \leq \tau(1 - L^R) & \quad (19)
\end{align*}
\]

5 Numerical Example

To illustrate the effective of the proposed model, a randomly generated set of data was created as displayed in Table 1 involving 20 DMUs, with three inputs \(X_1, X_2, X_3\) which are shared in two stages, two outputs \(Y_1, Y_2\), and one intermediate product \(D\). In our study, we supposed that only a part of intermediate product \(D\) are treated as inputs in the second stage, and the rest of intermediate product are final output. Supposed that there is a fixed cost \(R = 100\) should be allocated between those two stages. The fixed cost can be treated as an additional input adding in each stage.
5.1 Allocation plan under situation 2.1

Here we suppose that $X_1, X_2$ and $X_3$ are treated as shared inputs as $\alpha_1X_1$ and $(1-\alpha_1)X_1$, $\alpha_2X_2$ and $(1-\alpha_2)X_2$, $\alpha_3X_3$ and $(1-\alpha_3)X_3$ between the two stages. The lower bound and upper bound are specified as $0.4 \leq \alpha_1 \leq 0.6$, $0.25 \leq \alpha_2 \leq 0.75$, and $0.55 \leq \alpha_3 \leq 0.75$. Besides, this paper supposes the value range of intermediate measure use in the second stage is $0.4 \leq \beta \leq 0.6$, and the value range of fixed cost is $0.5 \leq \eta \leq 0.6$. After calculating with model (10), it exists common sets of weight which make efficiency score be 1 in each stage. Fixed cost allocation plans according to different procedures are shown in table 2. Values under stage1, stage2 are the amount of fixed cost at stage1 and stage 2 respectively. Satisfaction ($\rho$) under different procedure is also listed in table 1. We find all $\rho$ are 0.5550 under procedure 1 because of a large number of variables in the model. Similarly, the similarities ($\tilde{Q}$) are equal (0.5543) under procedure 3.

5.2 Allocation plan under situation 2.2

This paper supposes proportions of shared inputs are $\alpha_1 = 0.43$, $\alpha_2 = 0.25$, and $\alpha_3 = 0.55$, the proportion of intermediate measure used in second stage is $\beta = 0.4$, and the proportion of fixed cost is $\eta = 0$. Under these assumptions, we obtain no common set of weights larger than 0 makes overall efficiency be 1. Then it should be calculated the following process under situation 2.2. Notice that this paper supposes an extreme situation that $\eta$ equals zero. In real cases, fixed cost should be allocated in both stages. The results are shown in table 4. $e^*_n$ is the pre-allocating overall efficiency of $DMU_0$ by using model (6), $e(n, j)$ ensures the overall efficiency for all $DMU_j$ could be the maximum, while the overall efficiency score of $DMU_n$ will not be changed. We should apply allocation plan of $e(12, j)$ because the overall efficiency of $e(12, j)$ are the maximum(18.6849). $e^1,e^2$ and $E$ are the efficiency value in stage 1 and stage 2, and
system efficiency value respectively under this allocation plan. \( r_{12}^2 \) is the fixed cost in the second stage, also the total fixed cost because we suppose \( r_{12}^1 \) is zero.

6 Conclusions

Based on a two-stage network process with shared input resources to both stages, this paper develops models for DMUs that add and allocate fixed cost as an additional input in each stage. In reality, many DMUs actually have this kind of structures. Banks allocate fixed cost of a management system, online bank, and advertise for their branches. A similar situation exists in Hospital, chain supermarkets etc. There are three main strengths in models proposed by this paper. First, our models could be transformed into an existing model by changing values of \( o_{1_i} \) and \( o_{2_j} \). For example, if \( o_{2_j} = 1 \), the models proposed by this paper will be a general two-stage network DEA model. Second, in most situations, the allocation plan obtained by our models can make efficiency value of all DMUs be 1 under the same common set of weights.

Finally, we developed a numerical example to examine the effectiveness of the proposed models, and the current models are under the assumption of CRS (constant return of scale), how to modify these models under the assumption of variable VRS (Variable return of scale) will be a direction for future research.
References


Figure 1 Two-stage network DEA structure

\[ Y_{rj}, r = 1, \ldots, s \]

\[ (1 - \beta_d) z_{dj} \]

\[ X_{i3j}, i_3 \in I_3 \]

First stage

\[ \alpha_{i_2} X_{i3j}, i_2 \in I_2 \]

\[ (1 - a_{i_2}) X_{i3j}, i_2 \in I_2 \]

\[ \beta_d z_{dj}, d = 1, \ldots, D \]

Second stage

\[ X_{i1j}, i_1 \in I_1 \]

\[ \alpha_{i_2} X_{i2j}, i_2 \in I_2 \]

\[ (1 - \alpha_{i_2}) X_{i2j}, i_2 \in I_2 \]

\[ X_{i3j}, i_3 \in I_3 \]

\[ Y_{rj}, r = 1, \ldots, s \]
Figure 2 inputs and outputs in a two-stage network process

\[ X_{i_1j}, i_1 \in I_1 \]
\[ X_{i_2j}, i_2 \in I_2 \]
\[ X_{i_3j}, i_3 \in I_3 \]

First stage

Second stage

\[ \eta R \]
\[ (1 - \eta) R \]

\[ (1 - \beta_d) z_{d_1} \]

\[ (1 - \alpha_i) x_{i_2j}, i_2 \in I_2 \]

\[ (1 - \alpha_i) x_{i_3j}, i_3 \in I_3 \]

\[ \beta_d z_{d_1}, d = 1, ..., D \]

\[ Y_{rj}, r = 1, ..., s \]

\[ DMU_1 \]
\[ DMU_{n}, J = 2, ..., n \]

Northeast Decision Sciences Institute 2017 Annual Conference
Table 1: A random dataset

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Table 2 Fixed cost allocation plan at two stages

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Table 3 Allocation plan of shared resources at two stages

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Table 4 Efficiency values at various stages under situation 2.2 and the allocation proportion of fixed cost

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Project Scheduling to Maximize Expected Quality in the Presence of Stochastic Time Delays

Abstract

We present research designed to help deal with probabilistic time delays which endanger project quality. We first present our model of quality as a continuous function of time and cost (investment/expenditure) for individual tasks, \( Q(t, c_i) \), with a functional form similar to a quadrant of a bivariate normal distribution:

\[
Q(t, c) = Ke^{-\left[\left(\frac{t - \mu_t}{\sigma_t}\right)^2 + \left(\frac{c - \mu_c}{\sigma_c}\right)^2\right]},
\]

The quality of the overall project can then be defined, for example, as the minimum quality of the individual tasks (analogous to the strength of a chain being determined by its weakest link). In earlier papers, we have mentioned how our approach could be used to recalculate planned times, expenditures, and schedules in the presence of a significant time delay or cost overrun using the following formulation:

Maximize \( Q_{\min} \)
subject to:

\[
\begin{align*}
Q_{\min} & \le q_i, \quad i = 1, 2, \ldots, N \\
q_i & = Q_i(t_i, c_i) = K \exp \left\{-\frac{(t_i - \mu_{t_i})}{\sigma_{t_i}} - \frac{(c_i - \mu_{c_i})}{\sigma_{c_i}}\right\}, \quad i = 1, 2, \ldots, N \\
\sum_{i=1}^{N} c_i & \le C_{UB} \\
s_0 & = 0 \\
s_k & \ge s_i + t_i \quad \forall i = 0, \ldots, N, \forall k \in S_i \\
s_{N+1} & \le T_{UB} \\
s_i & \ge 0 \quad \forall i = 1, \ldots, N + 1 \\
t_i & \ge t_{\min}, \quad i = 1, 2, \ldots, N \\
c_i & \ge c_{\min}, \quad i = 1, 2, \ldots, N \\
t_i & \le \mu_{t_i}, \quad i = 1, 2, \ldots, N \\
c_i & \le \mu_{c_i}, \quad i = 1, 2, \ldots, N \\
q_i, t_i, c_i & \ge 0, \quad i = 1, 2, \ldots, N
\end{align*}
\]

In this paper, we begin the process of examining how much benefit might be possible from such re-calculation. For example, if we put a stochastic distribution on possible time delays (e.g., as a shift in a time parameter value of the quality function), how much better could we do (in terms of overall expected quality of the project) by such re-calculation, versus the simplistic/myopic/oblivious responses of either: (1) extending the scheduled time/s of delayed tasks to add in the delay/s and then cutting times of tasks at the very end of the project, or (2) maintaining the original planned times for tasks, thus cutting the effective time of the delayed task/s? Because of the time delay, the overall quality of the project will go down; the only question is how to minimize the
reduction. We present simulations to find the optimal planned durations for tasks and the scheduling protocol that maximize the expected overall project quality by applying our continuous quality function in terms of the time and expenditure put into it. We then show the improvement in quality possible from these recalculations vs. the two simplistic responses to delays mentioned above.

**Keywords:** project management, project scheduling, quality, stochastic optimization
Random Points in a Circle May Not Distribute Uniformly

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ABSTRACT

This article addresses the issue of distributions of points randomly generated in a circle. This issue comes from an application of Monte Carlo method in which a sample of families is picked for a statistical study in a circular region of a city and the families in the sample are required to be uniformly distributed. Does any random method generate a uniform sample? We have simulated four methods in computer and tested the uniformness of the points generated. The results show that randomness of a method does not warrant uniformness of the points in a two-dimensional circle, although it does on a one-dimensional line segment. One must be cautious that a random sample in a circular region may not be valid in terms of uniformness.

1. PROBLEM DEFINITION

The problem to be addressed in this article comes from an issue in an application of Monte Carlo method in a statistical study. A random sample of families is to be selected in a circular area two miles or less from the center of the city. The families selected for the sample are required to be random and uniformly distributed in the circle. That is, a valid sample must satisfy ‘randomness’ and ‘uniformness’ in the circle with radius of two miles. The problem is: Does any random method select a valid sample? Particularly, for example, if we pick a family on a randomly selected street each time, does it give us a sample whose elements are uniformly distributed?

That sampling issue is abstracted to a general one for Monte Carlo method: How to select points in a two-dimensional circle so that they are uniformly distributed? Will the points randomly selected by any method distribute uniformly and homogeneously? If not, what methods are not valid, and what methods are valid?

The streets in the 2-miles circled area of a city can be viewed approximately as chords of the circle. There are literatures of investigating random chords, most of which are concerned about Bertrand Paradox. Bertrand Paradox was put forward in 1889 about randomly generated chords in a circle (Bertrand, 1889). After 122 years of efforts of scholars, the paradox was resolved: Bertrand Paradox had perplexed people for more than a century because people mistakenly put an equal sign between random chords and uniformly distributed chords (Wang and Jackson, 2011). The resolution of Bertrand Paradox alerts people that “uniformness” does not necessarily go with “randomness” in a two-dimensional space.

2. UNIFORMLY DISTRIBUTED POINTS AND CHORDS IN A CIRCLE

Uniformly distributed points are homogeneously distributed (Ross, 1985). In a one-dimensional system, uniform distribution is well defined. Let \( T \) denote a line segment \([a, b]\), let \( t \subset T \) be a part of \( T \). A set of random points are uniformly distributed over \( T \) if the density of points in \( t \) remains same statistically no matter where \( t \) is in \([a, b]\).
For a two-dimensional circle, let C denote the circle, s denote a square within the circle. The set of random points in circle C is uniformly distributed if the density of points in s remains same statistically no matter where s is positioned in the circle.

Uniformly distributed chords in a circle are defined as: A set of chords in circle C is uniformly distributed if for any square s in C, probability that a chord passes through s remains same statistically and the directions of the lines passing through s are uniformly distributed over the range \([0^\circ, 180^\circ]\). (Wang, 2014) Note that here we have used the concept of uniform distribution in a one dimensional space as defined above.

The above definition of uniformly distributed points in a circle C tells not only what uniformly distributed random points are, but also the way to test the uniformness of randomly generated points.

3. SIMULATIONS OF RANDOM POINTS IN A CIRCLE

There are many ways of generating random points in a circle. The points generated by any of those methods are undoubtedly random. But are they uniformly distributed? We have tested four methods with the computer simulations on MS Excel spreadsheets by checking the uniformness of points. For each method, we generated hundreds of thousands of points, and then check their uniformness. The circle in our simulations is \(X^2+Y^2=100^2\), a circle C with radius 100 and center at the origin point.

3.1. Methods of Generating Random Points

Uniformness of the points randomly generated by the following four methods is tested in our computer simulations.

Method 1.

This method picks points randomly on the chords of C, and each chord is created by two random points on the circle C.

Step 1. Randomly generate a point f on circle C;
Step 2. Randomly generate a point g on circle C;
Step 3. Draw a chord H of C by connecting f and g;
Step 4. Randomly pick a point on chord H between f and g.
Step 5. Repeat from Step 1.

Method 2.

This method picks points randomly on chords, and each chord is generated by “throwing broom straws” which simulates dropping broom straws on a circle on the floor (Jayne, 1973).

Step 1. Generate a line L in square \((-2000\leq X\leq 2000, -2000\leq Y\leq 2000)\) by two random points in the square;
Step 2. If L does not intersect circle C \((X^2+Y^2=100^2)\), then go to Step 1, otherwise go to Step 3;
Step 3. Find the intersection points f and g of line L and circle C;
Step 4. Randomly pick a point on chord (f, g);
Step 5. Repeat from Step 1.

Note that the square \((-2000\leq X\leq 2000, -2000\leq Y\leq 2000)\) is much larger than circle C so as to mimic “throwing broom straws” to the floor which is assumed to be boundless.

Method 3.

This method randomly picks a point’s X coordinate value and Y coordinate value independently, and the point counts only if the selected point is in circle C.

Step 1. Randomly pick x such that \(-100\leq x\leq 100\), and randomly pick y such that \(-100\leq y\leq 100\).
Step 2. If point \((x, y)\) is not in circle \(C\) (i.e., \(x^2+y^2>100^2\)), then go to Step 1, otherwise go to Step 3.
Step 3. \((x, y)\) is a point selected.
Step 4. Repeat from Step 1.

Method 4.

This method picks points randomly on the chords of \(C\), and each chord is created with two random points inside the circle \(C\) selected by Method 3. The purpose of testing this method is to see the effect of some additional random steps on top of random points generated by Method 3.

Step 1. Randomly generate a point \(f\) inside circle \(C\) by Method 3;
Step 2. Randomly generate a point \(g\) inside circle \(C\) by Method 3;
Step 3. Draw a chord \(H\) of \(C\) by connecting \(f\) and \(g\);
Step 4. Find the intersection points \(f'\) and \(g'\) of chord \(H\) and circle \(C\);
Step 5. Randomly pick a point on chord \(H\) between \(f'\) and \(g'\).
Step 6. Repeat from Step 1.

3.2. Testing Uniformness of Points in Computer Simulations

The definition of uniformly distributed random points in a circle in Section 2 implies the way of testing the uniformness of randomly generated points. In our computer simulations, we used a 20-by-20 square \(s\), which is much smaller than circle \(C\), \(x^2+y^2=100^2\), and positioned the small square \(s\) at a couple of places in the circle. Number of points in square \(s\) at a place is compared to those at other places so as to see whether the points in circle \(C\) are uniformly distributed.

The area of the circle \(C\) is \(\pi(100)^2=31,416\). The area of the small square \(s\) is \(20\times20=400\). The ratio of the two areas is therefore \(400/31,416 = 0.012734\). It means that if the points in the circle were homogeneously distributed, then the ratio between (number of points in square \(s\)) and (number of points in circle \(C\)) should be close to 0.012734.

3.3. Results of Simulations

The simulation results and are presented in the tables below.

The first column in the tables below gives the positions of the 20X20 square \(s\). For example, if the center of \(s\) is at \((X=50, Y=0)\), then the square would be \((40\leq X\leq60, -10\leq Y\leq10)\). In the simulation, we placed square at three positions along X-axis, three positions along Y-axis, and three positions along the radius on line segment \(Y=X\).

Since the ratio between the square area 400 and circle area 31,416 is \(h=0.012734\), if the points in the circle \(C\) are uniformly distributed, then ratio between number of points in square \(s\) and number of points in circle \(C\) should be near 0.012734. So, \(h\) is a benchmark of uniformness of points.

\(N_c\) stands for number of points generated in circle \(C\). \(N_s\) stands for number of points in the square \(s\).

SP stands for square proportion which is the ratio between \(N_s\) and \(N_c\), that is \(SP = N_s/N_c\). SP value is an indicator of uniformness. If values of SP are consistently near \(h=0.012734\) no matter where the square \(s\) is positioned in the circle \(C\), then the points are uniformly distributed, otherwise the points are not uniformly distributed.

Table 1 below shows the test results of simulations for Method 1 of generating random points in a circle, which picks points randomly on the chords of \(C\), and each chord is created by two random points on the circle \(C\). Total number of points generated in this test is 400,000. The values of square proportion, SP, vary significantly with the positions of square \(s\), and they are far from the benchmark of uniformness \(h=0.012734\). Therefore, we can conclude that the random points thus generated are not uniformly distributed in circle \(C\).

Table 1. Simulation Results for Method 1.

\[
\begin{array}{c|c}
N_c & \text{SP} \\
\hline
400,000 & \text{near 0.012734} \\
\end{array}
\]
Table 2 below shows the test results of simulations for Method 2 of generating random points in a circle, which picks points randomly on chords, and each chord is generated by “throwing broom straws”. To simulate “broom straws” being thrown to a boundless floor, we generate two points to represent a broom straw in area \((-2000 \leq X \leq 2000, -2000 \leq Y \leq 2000)\). The square \((-2000 \leq X \leq 2000, -2000 \leq Y \leq 2000)\) is much larger than circle \(C, X^2 + Y^2 \leq 100^2\), so as to mimic “throwing broom straws” to the boundless floor. A chord of \(C\) is generated only if the “broom straw” intersects the circle \(C\). Total number of points generated in this test is 600,215. The values of square proportions, \(SP\), vary with the positions of the square \(s\), and they are significantly different from the benchmark of uniformness \(h=0.012734\). Therefore, we can conclude that the random points thus generated are not uniformly distributed in circle \(C\).

Table 2. Simulation Results for Method 2.
\[N_C = 600,215.\]

<table>
<thead>
<tr>
<th>center of square (s)</th>
<th>number of points in square (s)</th>
<th>square proportion, (N_s / N_C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(X=0, Y=0)</td>
<td>3,177</td>
<td>0.7943%</td>
</tr>
<tr>
<td>(X=50, Y=0)</td>
<td>2,883</td>
<td>0.7208%</td>
</tr>
<tr>
<td>(X=87, Y=0)</td>
<td>2,051</td>
<td>0.5128%</td>
</tr>
<tr>
<td>(X=0, Y=50)</td>
<td>3,271</td>
<td>0.8178%</td>
</tr>
<tr>
<td>(X=0, Y=87)</td>
<td>8,509</td>
<td>2.1273%</td>
</tr>
<tr>
<td>(X=30, Y=30)</td>
<td>3,032</td>
<td>0.7580%</td>
</tr>
<tr>
<td>(X=55, Y=55)</td>
<td>3,803</td>
<td>0.9508%</td>
</tr>
</tbody>
</table>

Table 3 below shows the test results of simulations on Method 3 of generating random point in circle \(C\), which picks a point’s \(X\) coordinate value and \(Y\) coordinate value independently in the area \((-100 \leq x \leq 100, -100 \leq y \leq 100)\), and if \((x, y)\) is within \(C\) then this point counts otherwise this point is discarded. Total number of points generated in this test is 1,201,277. The values of square proportions, \(SP\), are consistently close the benchmark of uniformness \(h=0.012734\), which show the uniformness of the points thus generated.

Table 3. Simulation results for Method 3.
\[N_C = 1,201,277.\]

<table>
<thead>
<tr>
<th>center of square (s)</th>
<th>number of points in square (s)</th>
<th>square proportion, (N_s / N_C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>(X=0, Y=0)</td>
<td>15,174</td>
<td>1.2632%</td>
</tr>
<tr>
<td>(X=50, Y=0)</td>
<td>15,260</td>
<td>1.2703%</td>
</tr>
<tr>
<td>(X=87, Y=0)</td>
<td>15,192</td>
<td>1.2647%</td>
</tr>
<tr>
<td>(X=0, Y=50)</td>
<td>15,181</td>
<td>1.2637%</td>
</tr>
<tr>
<td>(X=0, Y=87)</td>
<td>15,312</td>
<td>1.2746%</td>
</tr>
<tr>
<td>(X=30, Y=30)</td>
<td>15,399</td>
<td>1.2819%</td>
</tr>
</tbody>
</table>
Table 4 below shows the test results of simulations for Method 4 of generating random points in a circle, which picks points randomly on the chords of C, and each chord is generated from two random points inside the circle C selected by using Method 3. Total number of points generated in this test is 801,390. The values of square proportions, SP, vary significantly with the positions of the square s, and they are far from the benchmark of uniformness $h=0.012734$. Therefore, we can conclude that the random points thus generated are not uniformly distributed in circle C.

<table>
<thead>
<tr>
<th>center of square s</th>
<th>$N_s$: number of points in square s</th>
<th>SP: square proportion, $N_s / N_C$</th>
</tr>
</thead>
<tbody>
<tr>
<td>X=0, Y=0</td>
<td>4,372</td>
<td>0.5456%</td>
</tr>
<tr>
<td>X=50, Y=0</td>
<td>11,940</td>
<td>1.4899%</td>
</tr>
<tr>
<td>X=87, Y=0</td>
<td>8,441</td>
<td>1.0533%</td>
</tr>
<tr>
<td>X=0, Y=50</td>
<td>11,711</td>
<td>1.4613%</td>
</tr>
<tr>
<td>X=0, Y=87</td>
<td>8,602</td>
<td>1.0734%</td>
</tr>
<tr>
<td>X=30, Y=30</td>
<td>12,563</td>
<td>1.5677%</td>
</tr>
<tr>
<td>X=55, Y=55</td>
<td>9,172</td>
<td>1.1445%</td>
</tr>
</tbody>
</table>

### 3.4. Summary of Simulation Results

For Method 1, Method 2, and Method 4, the values of SP go up and down when the square s is placed at different positions in the circle C. Meanwhile, for Method 3, SP values consistently remain very close to the benchmark of uniformness $h=0.012734$ regardless the positions of square s. So, we can see that, of the four methods, only Method 3 generates uniformly distributed random points in a circle; and the points generated by the other three methods are not uniformly distributed, and are far from uniform distribution.

The chords generated by Method 1 and Method 4 were proved to be not uniformly distributed (Wang and Jackson, 2011). It is not surprising that the random points created from those chords are not uniform.

However, the chords generated by Method 2, “throwing broom straws”, were proved to be uniformly distributed in the circle, theoretically and experimentally (Jayne, 1973). Our simulations show that the points randomly picked on those uniformly distributed chords are not uniformly distributed!

It is interesting to compare Method 3 and Methods 4. Method 4 takes a few more random steps on the random points generated by Method 3. As the simulation results show, points generated by Method 3 are uniformly distributed, while the points generated by Method 4 are not. Let $P_3$ denote the set of points generated by Method 3, $P_4$ the set of points generated by Method 4. $P_4$ is generated from $P_3$ by picking a point on the chord formed by two points randomly selected from $P_3$. It turns out that $P_4$ is not uniformly distributed, although $P_3$ is. That is, the set of points, $P_4$, generated from a set of uniformly distributed points, $P_3$, are not uniform!

The simulation results alert us that if we generate random points on randomly picked chords, then the points are very much likely not uniformly and homogeneously spread over the circle. When randomly selecting a sample of families in a city, a convenient method is to select a street first, then pick a family on the street, which amounts to selecting a chord first then picking a point from that chord. Our simulations show that a sample generated by using such a method is not a homogeneous one.

To guarantee the uniformness of a set of random points in a circle, we need to generate its X-coordinate value and its Y-coordinate value independently, as we did in Method 3.
4. FURTHER RESEARCH
We will extend our research on randomness of samples from a circle to any constraint region, and from two-dimensional space to higher dimensional space, so as to deal with sample constraints in multiple aspects such as location, age, income, and education.

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Resource Planning and Job Scheduling for Project Management

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Abstract

Resource planning and job scheduling for project management entails selecting different types of resources each with varying costs and capabilities, assigning the selected resources to the jobs, and then scheduling these resources to complete the jobs while simultaneously satisfying all the timing coordination requirements. We model this problem on a time-space network, develop modeling enhancements, and propose a cutting plane procedure, combined with heuristics, which significantly outperforms standard solution methods. This model is motivated by the annual infrastructure maintenance planning decisions faced by the US freight railway industry, but also has its broad applications in many other transportation and telecommunication companies. Due to the complex coordination requirements and the vast number of resource selection, assignment, and sequencing choices, the maintenance planning problem has proved to be intractable in practice. We have successfully applied our model for a major US freight railway company to support its annual infrastructure maintenance planning efforts.
Supply Chain Network Capacity Competition with Outsourcing: 
A Variational Equilibrium Framework

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October 2016

Abstract This paper develops a supply chain network game theory framework with multiple manufacturers/producers, with multiple manufacturing plants, who own distribution centers and distribute their products, which are distinguished by brands, to demand markets, while maximizing profits and competing noncooperatively. The manufacturers also may avail themselves of external distribution centers for storing their products and freight service provision. The manufacturers have capacities associated with their supply chain network links and the external distribution centers also have capacitated storage and distribution capacities for their links, which are shared among the manufacturers and competed for. We utilize a special case of the Generalized Nash Equilibrium problem, known as a variational equilibrium, in order to formulate and solve the problem. A case study on apple farmers in Massachusetts is provided with various scenarios, including a supply chain disruption, to illustrate the modeling and methodological framework as well as the potential benefits of outsourcing in this sector.

Keywords: Generalized Nash Equilibrium, game theory, supply chains, capacity competition, outsourcing, variational inequalities, networks
Gaining Software Project Management Insights
From Open Source Software

KEY WORDS
Project management; Software metrics; Open source software (OSS); Predictive modeling; Early warning indicators (EWI); Software automation

ABSTRACT
Successful software product development requires strong technical skills, deep business acumen, complete understanding of user requirements, and project management expertise. This paper will focus on how to improve software project management methods through research and the use of publically available software data. While researchers have studied software project management for many years, they have openly acknowledged understandable challenges in obtaining reliable and unbiased project data from proprietary source software (PSS) development organizations. Open source software (OSS) communities have a wealth of data which researchers are able to leverage more easily and reliably. The external validity of OSS data for PSS related study has been long debated amongst researchers and practitioners. Even still, there have been numerous instances where the study of OSS data has undoubtedly provided valuable insights to researchers studying OSS development processes. For example, historical OSS data available for several performance related metrics such as software download rates, developer collaboration, defect rates, and release dates can serve as valuable predictors of process quality and user adoption levels for upcoming software. There are opportunities to encapsulate
these data points within the context of a predictive model for use by practitioners. Some of these opportunities will be explored in this paper.

The primary purpose of this research is to determine if and how OSS data can be leveraged to improve software project management practices. The paper will provide novel approaches to examining and applying OSS data to improve software project management practices. Use of machine learning algorithms will be explored to develop learning models which can be leveraged by web-based tools for project management and decision making. Preliminary findings, results, and implications will be shared. Opportunities for future research will be identified for further development and research.
An Empirical Study into the Influence of Transparency on Unethical Behaviors in the Workplace

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ABSTRACT

The prevalence of deviant behaviors in organizational settings necessitates a systematic and novel solution to deal with this problem. In recent years, transparency has gained rising favor as an organizational principle and managerial goal, yet little was known about the effect of transparency on preventing unethical behaviors in organizations. Therefore, this research was conducted to explore the potential influence of transparency on unethical behaviors in the workplace. The Ferrell and Gresham’s (1985) contingency model of ethical decision making was adopted to understand factors that could have an impact on the reasoning process of individuals to reach ethical/unethical decisions. At the same time, Ferrell and Gresham’s (1985) model helped to identify the position as well as the role of transparency in that process. The survey research method was implemented to examine proposed research questions. Thirty-one unethical behaviors categorized into four groups, including production deviance, property deviance, political deviance and personal aggression, were selected as scenarios to measure the impact of transparency. Data was collected through a self-administered questionnaire on two hundred and three employees. The results revealed that transparency can help to reduce production deviance, political deviance and one type of personal aggression, namely sexual harassment. However, the effect of transparency on property deviance was not identified. Findings provide some implications for managers and policy makers to minimize the incidence of unethical behaviors in the workplace.

Keywords: Ethical Decision Making Model, Transparency, Unethical Behaviors, Workplace.
The Dynamics of Punishment and Trust

Abstract

The trade-off between mercy and justice is a classic moral dilemma, particularly for organizational leaders and managers. In three complementary studies, we investigated how resolving the ‘punishment dilemma’ influences interpersonal trust. Study 1 used controlled scenarios to show that uninvolved observers trusted leaders who administered large or medium punishment more than leaders who administered no punishment when transgressors deserved punishment. At the same time, large punishment decreased trust more than medium or no punishment for less deserving targets. Study 2’s similar scenarios showed that leaders who administered punishment lost trust when they subsequently received benefits even though it was not clear whether their benefits resulted from their act of punishment. Study 3 provided a behavioral replication of these results. These findings suggest that people trusted punishers more than non-punishers, but only when punishers’ motives were not personal revenge. In the discussion, we explore the practical and theoretical implications of these results for organizations.
Buyer and supplier strategies for hedging against risk in the ethanol industry

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Biofuels such as ethanol have been increasingly used as a substitute for fossil fuel energy and its adoption has been accelerated by government mandates across the globe. Although ethanol is a very important energy source and the risks and uncertainties associated with ethanol production and sale makes it a prime target for hedging and other forms of risk management, very little work has been done in the literature on that topic. Recognizing that gap in the literature, this paper examines hedging strategies available to ethanol manufacturers such as futures, swaps and options. We utilize Platts, a market that is used by most commodity traders as a trusted source of trading and information on the market. We also introduce a number of methodological approaches that have not been traditionally used in the hedging literature. Traditionally, hedgers seek to take equal and opposite positions in related markets and more complex models seek to exploit use of correlations without incorporating dependent relationships. We utilize copula in this paper since it allows for the incorporation of non-standard dependencies, thus better reflecting conditions faced by ethanol processors. We also utilize mean reversion which enables us to capture volatility differently by considering a deterministic and stochastic side of the price. By doing so, we are able to capture upside and downside risks more accurately, thus giving us extra flexibility in forecasting returns. We also utilize multi-cut benders decomposition and sample average approximation approaches that enable us to solve the problem at hand more efficiently while using fewer data points.

There are six main contributions of this study: 1) Explore the different hedging strategies
available to ethanol producers, a topic that has been inadequately covered in the literature. 2) Integrate financial and operational hedging risks in our model in order to provide a more complete assessment of the problem than focusing only on financial risks. 3) Utilize copula to capture a better dependency structure which enables us to extend one to one relationship of prices (corn and ethanol) beyond correlation 4) Utilize a Multi-cut Benders Decomposition methodology and also sample average approximation in order to help with efficient computation of the hedged profit margins while using smaller sample data 5) Model the buying (corn and cellulosic feedstock) and selling (ethanol end-product) prices to follow a mean reversion (MR) in order to more accurately capture price volatilities 6) Provide managers in ethanol manufacturing companies with risk managing strategies through hedging, that can enable them to increase profits and shareholder wealth.
EFFECTS OF FIRM SIZE ON EXPECTATIONS OF QUALITY MANAGEMENT SYSTEM
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ABSTRACT
The purpose of this study is to test whether the size of a firm, in terms of number of employees, has any effect on the firm’s expectations of a quality management system. ISO 9001 is the most popular and implemented quality management system in the world. In this study, Factor Analysis is applied to measure how much improvement was experienced, as a result of the implementation of ISO 9001 in the following areas: Quality, Cost, Flexibility, Dependability, Customer Satisfaction, Profitability, and Market Share. The analyses indicate that there are no significant differences in seeing improvements in seven areas due to the size of the organization. Two areas that saw the most improvements are Quality and Customer Satisfaction.

Keywords: Customer Satisfaction, Factor Analysis, Firm Size, Quality
PROCESS CAPABILITY ANALYSIS FOR VARIABLES WITH ONE-SIDED SPECIFICATION LIMIT AND NO NOMINAL VALUE

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ABSTRACT

The objective of this paper is to propose an approach to monitor the capability of a process with respect to variables that have a one-sided specification limit when there is no nominal value given. This approach can be used to monitor the capability of those variables over time with respect to their specification limits.

Key words: Process capability, one-sided specification limit, no nominal value.

INTRODUCTION

This research is a continuation of our previous works in process capability. In one of our earlier works, we developed a methodology to determine the optimal location of the process mean when the process capability is low [7]. In a different study, we looked at the issue of estimating process capability when the process is not stable, i.e., not in statistical control [2]. In another work, we proposed a method to determine the process capability when there is a natural and steady shift in the process average [4]. In our more recent study, we developed a method to monitor the quality level of the key process variables to make sure that they are Six Sigma capable under the assumption that the process variables are independent, i.e., not correlated [5]. In this paper we will propose an approach to monitor the capability of the process variables that have a one-sided specification limit and no specified nominal value.

PROPOSED METHOD

Process capability tools, such as Cp, Cpk, Cpu, Cpl, etc., are commonly used to evaluate the process capability under the assumption that the process variables follow Normal or near Normal distribution. In this paper we will look at a special case where the specification limit is one-sided and no nominal is given.

The proposed measure will create a pseudo nominal value by using an estimate of “capability standard deviation.” The “capability standard deviation” is the standard deviation estimate; this is independent of changes in the process average, such as \( \overline{R} / d_2 \) or \( \bar{s} / c_4 \), where \( \overline{R} \) and \( \bar{s} \) are the average of the subgroup (sample) ranges and the average of the subgroup standard deviations, respectively, and \( d_2 \) and \( c_4 \) are correction factors for a given subgroup size. Another estimate of
capability standard deviation would be the one that uses mean square successive differences (MSSD). MSSD can be defined as

\[
MSSD = \frac{1}{n-1} \sum_{i=1}^{n-1} (X_{i+1} - X_i)^2
\] (1)

Using these differences, an unbiased estimate for the process variance is given as:

\[
q^2 = \frac{1}{2(n-1)} \sum_{i=1}^{n-1} (X_{i+1} - X_i)^2
\] (2)

MSSD standard deviation, \(\sigma_{MSSD}\), then would be

\[
= \sqrt{q^2}
\] (3)

The capability standard deviation of the process could differ from the regular, conventional standard deviation, if the process currently is not statistically stable. These estimates, i.e., the capability standard deviation and the regular standard deviation, would be very close to each other if the process is in control, i.e., stable. See, for example, Neumann, et al. [6], Hald [1], Holmes and Mergen [2], [3]) for how to estimate the capability standard deviation using the MSSD approach.

The next step would be to set the implied nominal value using the capability standard deviation described above. That could be done as follows:

\[
\text{LSL} + k\text{SD or USL} - k\text{SD}
\]

where LSL and USL are the lower and upper specification limit, respectively, SD is an estimate of the capability standard deviation, and k is a multiplier. This implied nominal can also be a reference for the process average, i.e., centering the process properly.

For example, to be able to maintain the same minimum requirement of the capability indices, i.e., 1.33, the nominal value can be set, for example, 4 standard deviations away from the given specification limit (i.e., k = 4), which would yield a Cpl or Cpu value of 1.33, assuming a Normal distribution.

\[
\text{Nominal} = \text{LSL} + 4\text{SD}
\]
or

\[
\text{Nominal} = \text{USL} - 4\text{SD}
\]

Assuming a Normal distribution, then a Z statistics for a variable \(X_i\) can be generated. For example, if only USL is given:
where \( X_{it} \) represents the value of variable \( i \) at time \( t \) and \( Z_{it} \) is the corresponding Z statistics for variable \( i \) at time \( t \).

As long as Z values are zero or near zero, we can say that the process average is on or near the implied nominal value we set and the process maintains the desired capability; i.e., \( X \) values are on or near target.

Similar Z values can be computed for those variables with only a lower specification limit:

\[
Z_{it} = \frac{X_{it} - (LSL_i + 4SD_i)}{SD_i}
\]  

(5)

The same comment also goes for the LSL case too; i.e., Z values of zero or near zero imply that the process average is on or near the implied nominal value we set and the process maintains the desired capability, i.e., \( X \) values are on or near target.

These Z values can be monitored over time for each variable to make sure that we maintain the minimum required capability, e.g., Cpu or Cpl = 1.33. Alternatively, the average of the process can also be used as the implied nominal, if the process average is found stable based on the process control study.

Also, if the standard deviation (SD) is large, one may want to set the nominal further away from the specification limits until the improvement studies are completed to reduce the variation in the process.

**EXAMPLE**

Let’s assume that we are monitoring two process variables, \( X_1 \) and \( X_2 \). Let’s also assume that the USL and the capability standard deviations (SD) for these variables are:

\[\text{USL}_1 = 10, \text{SD}_1 = 1\]

and

\[\text{USL}_2 = 6, \text{SD}_2 = 0.5\]

and let the target for each variable set at USL - 4SD. Thus, the nominal values for \( X_1 \) and \( X_2 \) would be 10-4(1) = 6 and 6-4(0.5) = 4, respectively.

For the following past observations on these two process variables, the \( Z_{it} \) values can be determined as follows by using equation (4):
During this time period variable $X_1$ seems to be on or near its nominal value. The highest $Z$ value is 1.5, which indicates that during the period when the samples are taken the most extreme value for variable $X_1$ was only 1.5 standard deviations away (i.e., above) from the implied nominal value for $X_1$. Whereas variable $X_2$ is displaying an increasing trend and steadily getting away from its implied nominal value of 4, which requires an investigation.

These $Z$ values for each variable can also be plotted on a trend chart or an individual process control chart, for example, to monitor their capability over time.

**CONCLUSION**

In this paper, we are proposing an approach to monitor the capability of a process with respect to variables that have a one-sided specification limit when there is no nominal value given. Proposed statistics can also be combined with the control charts to monitor the process capability overtime. Our approach is based on the assumption that process follows Normal distribution. Further research should be done for non-Normal process distribution.

**REFERENCES**


Impact of Total Quality Management on Organizational Performance: Exploring the Contingent Effects of Organizational Learning and Innovation

Key words: TQM, organizational learning, innovation, organizational performance
Note: working paper, please forward all comments and questions to Mohsen Modarres
Impact of Total Quality Management on Organizational Performance: Exploring the Contingent Effects of Organizational Learning and Innovation

Abstract

Total Quality Management involves integrated and dynamic processes. Previous researchers have endeavored to examine the relationship between TQM and organizational performance by untangling the major components of the TQM, such as learning capabilities and process and product innovations. However, past studies have neglected to examine the mediating impact of organizational learning capabilities and innovations on the relationship between TQM and organizational performance. In the present research we explored the mediating impact of organizational learning and innovations on the TQM-performance relationship. Our results revealed that TQM has a positive and significant association with both organizational learning and innovations. Moreover, organizational learning and innovations were positively and significantly associated with organizational performance. Findings, however, revealed a weak and non-significant relationship between TQM and performance.
Introduction

In recent years fundamental changes in competitive forces in global marketplace has reduced resource availability and pressured organizations to adopt quality management practices and select innovative strategies (e.g., Zehira, Ertoşunb, Zehirc & Müceldillid, 2012; Tushman & Anderson, 1986) and enhance learning capabilities (e.g., March, 1991), to improve performance and remain competitive by coaligning their core competences with shifts in marketplace (e.g., Ireland, Hitt & Hoskisson, 2008; Porter, 1996). Previous research has revealed that organizations adopt quality management practices, primarily, to improve their overall performance. However, the findings on the relationship between quality management and performance have been paradoxical. Such inconsistency in past research can be, in part, attributed to multiple dimensions of the quality management and performance measures and single construct used by researchers (e.g., Kaynak, 2003). Furthermore, previous researchers have paid little attention to the contingent effects of organizational learning and innovation on the relationship between quality management and organizational performance.

In present research, we attempt to broaden and expand the research on the effect of quality management on corporation’s performance. We argue that previous research on quality management-performance relationship has not provided information about interactive effect of quality management with organizational learning and innovations to explain performance variations within corporations. We draw from contingency theory, neglected in recent quality management studies, to examine both the mediating and the interactions between quality management and two important variables, organizational learning and innovations in explaining various levels of performance. Furthermore, we explore the mediating effects of organizational
learning on quality management-innovations relationship. The proposed model and hypotheses tested the direct and interaction effects quality management, organizational learning and innovation on various performance levels. We employed cross-sectional mail survey data collected from firms operating in Iran. The test of the structural model partially supported the proposed hypotheses. The implications of the findings for researchers and practitioners in food industry are discussed and further research directions are offered.

**Literature Review**

Total quality management is strategic orientation within organization. Internally, quality management, primary, focuses on top management commitment and support for allocation of valued resources on process improvements, product quality, employee participation, information sharing and learning among employees and innovation. A number of researchers have posited that quality management practices within corporations tend to improve overall performance in financial, human resources, product and service innovations, teamwork and learning processes (e.g., Terziovski & Samson, 2000; Prajogo, Sohal, 2003; Jaafreh & Al-Abedallat, 2012; Barrow, 1993). Externally, quality management centers attention on customer demand and expectations, procurement of high quality materials from suppliers (e.g., Vanichchinchai & Igel, 2011), and strategic adaptation to changes in marketplace. Potential market growth and competitive rivalry pressures top managers to have a greater willingness to take risks, tolerate uncertainty, and also assess the influence of market forces on the relation between corporation’s performance (e.g., Modarres & Park, 2009; Hoskisson, Hitt & Ireland, 2008). Quality management practices enables top executives to long term investment strategy in human capital, teamwork processes, innovations, individual, team and organizational learning (e.g., Hung, Lien, Yang, Wud & Kuo,
2010), and external focus in order to adapt to marketplace changes in a timely fashion (e.g., Wang, Chen & Chen, 2012).

**Organizational Learning and Quality Management**

Organizations change through learning new routines. Overtime, new routines tend to modify or replace the existing processes; however, coordination between change and continuous improvements and stability tends to be a difficult task. Standardization of exiting routines in quality management (ISO 900 series) reduces both resource costs associated with production processes and variability in the quality of goods and services produced. This permits the knowledge to flow across subunits and create organizational processes that are duplicable and high quality products and services that are reliable. Change and continuous improvements are attained through exploration of novel routines (e.g., March, 1991; Winter, 1971) and learning through teamwork, experimental simulation and engaging in continuous process reengineering (e.g., Modarres, Beheshti-Ardekani, 2004). Quality management creates an environment within organization which promotes an environment of learning and interaction of novel ideas. According to Conner and Prahalad’s (1996), quality management creates a mutual trust and information sharing among organizational members. The culture of trust and knowledge sharing (e.g., Hung, Lien, Yang, Wud & Kuo, 2010) creates an internal environment that generates a cognitive learning process through which diverse ideas and accumulated knowledge by members of the organization interact. Such interaction of knowledge leads to explorations of novel routines, introduction of new product and services, and implementation of new codes in organization. According to March (1991), adaptive organizations should develop learning
capability to exploit novel routines to create new core competencies. Exclusion of exploitation of novel ideas generated by employees is likely to position organizations trapped in suboptimal stable equilibria. That is, lack of proper and timely implementation new ideas leads to sub-optimal learning at organizational level and overall performance. Quality management, however, tends to be an enabler that assists individual and groups learning process (e.g., Barrow, 1993; Hung, Lien, Yang, Wu & Kuo, 2010), to exploit tacit and explicit knowledge in completion of cross-functional projects and enhance organizational learning and performance excellence (e.g., Senge, 1990).

**Hypothesis 1:** Quality management is positively associated with organizational learning.

**Hypothesis 1a:** Learning performance is positively associated with organizational performance.

**Innovation Performance and Organizational Learning**

Innovation tends to be one of many factors in success of business corporations. Innovation may lead to new products, processes and services. However, whether top managers of an organization are capable of successful exploitation of technological advances and translate innovation of new ideas or concept into improved goods and services is contingent on a number of critical factors such as, employee interactions and teamwork, decentralized decision-making, flexible and informal structure, subunit interconnectedness, allocation of resources toward change and instituting innovative culture by top management within an open system (e.g., Wheelen, Hunger, Huffman & Bamford, 2015). Previous researchers have posited that technological and product innovations are arguably an important factor in improving and maintaining competitive advantage and entrepreneurial mindset within organization (e.g., Hana,
Organizational innovation has been linked to novel methods explored to renew existing routines and learning process to change the existing codes with which organizations operate (e.g., Gunday et al., 2011). Moreover, innovation, according to Luecke and Katz (2003), creates capability to institute a culture that leads to reallocation of valued resources within organization toward new products and services and enhance corporate performance. Similarly, Singh and Smith (2004), posited that quality management practices create an environment within organizations that is conducive to innovation and creation of new product and services through team work and sharing critical information among employees. According to Hoang, Igel and Laosirihongthong (2006), the relationship between quality management and innovation is positively influenced by strategic view of top managers toward market segments in promoting innovative ideas and generating new product and services to match customer expectations. Such organic and interactions of ideas in organizational environment is supported by top executives and enables them to strategically position products and services to gain competitive advantage in marketplace. Learning capability tends to influence the speed and extent of new innovations, and timely adaptation to changes in the firm’s social, natural and legal environments. Creation of knowledge commits top executives to allocate resources to employees’ education, which plays an important role contributing to the individual and group learning and the generation of new ideas within organizations. Furthermore, top executives are strategically committed to positively reward motivated employees’ participation in knowledge sharing and experimenting novel ideas across subunits leads to more effective implementation of such novel ideas and enhance organizational performance.
Hypothesis 2: Quality management is positively associated with organizational innovation.

Hypothesis 2a: Organizational innovation is positively associated with learning performance.

Performance, Quality Management, Learning and Innovations

Performance has been described as desired outcome that may be attained through multiple, often subjective measures (e.g., Wheelen, Hunger, Hoffman & Bamford, 2015). As such, organizational performance has emerged as a multidimensional variable and remains unclear in its causal linkage organizations’ strategic orientation in general and to quality management practices in particular (Gomez-Gras & Verdu-Jover, 2005; Hasan and Kerr, 2003). The literature in quality management has been diverse and conflicting on quality management-performance relationship. A number of researchers have reported statistically no significant relationship between quality management and performance e.g., (Powell, 1995; Westphal, Gulati & Shortell, 1996). A number of studies have reported positive associations between organizational performance and quality management (e.g., Salaheldin, 2009; Demirbag, Tatoglu, Tekinkus, & Zaim, 2006). However, the positive association of quality management with performance, is primarily, mediated by knowledge created by members of organization and reallocation of organizational resources toward innovation of new products and services. Other researchers have posited the impact of quality management practices on performance should be measured in the long-term. Shahin (2006) in a longitudinal study examined subjective accounting measure to explore the association between quality management and performance. The findings of the study revealed quality management positively and significantly influences financial performance. Furthermore, findings by Shahin (2006) revealed that quality management has negative influence on debt to total assets ratio. Similarly, Jaafre and Ai-abedallat (2012) concluded that quality
management has positive influence on financial performance of the organization as well as innovation and human capital. Other researchers have examined both direct effects of quality management on performance and mediating effects of organizational learning and innovation on quality-performance relationship. Vanichchinchai and Igel (2011) study showed the positive association of supply chain on quality–performance relationship.

As indicated above, adaptive organizations should develop learning capability to exploit novel routines to create new core competencies. However, exclusion of exploitation of novel ideas generated by employees is likely to position organizations trapped in suboptimal stable equilibria (March, 1992). Moreover, strategic balancing between generating of novel ideas and learning through exploration and group interactions, require timely implementation across organization in order to gain competitive advantage and optimal organizational performance (e.g., Winter, 1987; March, 1991; Hana, 2013). According to (Galende & De la Fuente, 2003; Hana, 2013), quality management practices create a learning environment that permit individuals and teams exchange critical information and collaborate in completion of new projects. Furthermore, quality management process requires greater structural flexibility which enables employees’ interactions and teamwork to generate knowledge that leads to new products and services faster than other competitors. Innovation of new products and services through learning processes enhances organizational performance by taking advantage of opportunities in the marketplace and gaining competitive advantage (e.g., Hana, 2013).

**Hypothesis 3**: Quality management is positively associated with organization performance.
Methodology

Sample and Data

Data. The data used in this study were collected by survey method from “Food Industry in Iran.” The survey was carried out during the year 1394 (2015) and provided information on Iran’s food business environment, quality management, organizational learning, innovation performance, and organizational performance. The surveys were mailed to 400, randomly selected, senior managers or firm presidents. Top executives and senior managers represent the most appropriate sources of information for this study. A questionnaire and cover letter was mailed to the managing director or chief executive officer of each company. 149 of the 400 mailed surveys were returned. Hence, thirty seven percent of the completed surveys were used in the present investigation.

Measurement of variables

In this section we explain measures used in the present research, item analysis and also provide information on internal consistency reliability estimates. Quality management, is primarily, focused on continuous improvement, customer satisfaction, top management support, and employee involvement (e.g., Ross, 1993). To measure the effectiveness of quality management, the present research utilized 6 dimensions of, (1) top management support, (2) employee involvement, (3) continuous improvement, (4) customer focus, (5) education and training, (6) supply management (Vanichchinchai & Igel, 2011; Wang, Chen & Chen, 2012). This study assessed quality management using 25 measurement items from a sample of 149 respondents, he measurement items were adopted from previous studies.
Respondents were asked to indicate their levels of agreement with descriptive statements using a 5-point Likert scale (range, 1 = strongly disagree to 5 = strongly agree). Table 1 shows an examination of the Kaiser-Meyer Olkin measure of sampling adequacy suggested that the sample was factorable (KMO=.833); $\chi^2=3485$, df, 300, sig 0.000. We can reasonably describe each set of items as being indicative of an underlying factor for quality management. It shows that there is relationship among 6 items of QM factor. The component including TMS1-4, CF1-3, EDT1-4, CII1-3, SM1-4, EEN1-7. In additional, factor analysis is carried out with independent factors. Table 2 shows QM scale items, Table 3 shows orthogonal (VARIMAX) rotation of the factor matrix and Table 4 shows the results of a second-order CFA and the scale reliability on quality management dimensions that reached statistical significance. This indicates that criteria had a significant correlation with dimensions, and that the scale had convergent validity (Anderson & Gerbing, 1988).

<table>
<thead>
<tr>
<th>Table 1: KMO and Bartlett's Test of QM Variable</th>
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<tbody>
<tr>
<td>Kaiser-Meyer-Olkin Measure of Sampling Adequacy</td>
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<tr>
<td>Bartlett's Test of Sphericity</td>
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**Quality Management.** Quality management practices create an environment of shared information and facilitate incremental improvements and drastic changes in organization.

Primary tenant of quality management are continuous improvement, customer satisfaction, top management support, and employee involvement (e.g., Ross, 1994). To measure the effectiveness of quality management, this study used Structural Equation Modeling, quality
management was operationalised as a second-order latent variable measured by six first-order factors, top management support, employee involvement, continuous improvement, customer focus, education and training, and supply management (Vanichchinchai & Igel, 2011; Wang, Chen & Chen, 2012). This study assessed quality management using 25 measurement items adopted from previous studies (Vanichchinchai & Igel, 2011; Wang, Chen & Chen, 2012; Coyle-Shapiro, 2002). Respondents were asked to indicate their levels of agreement with descriptive statements using a 5-point Likert scale (range, 1 = strongly disagree to 5 = strongly agree). Factor analysis was used to identify unidimensional factors within the overall quality management. Table 2 (Please refer to Appendix I) presents the item scales; Table 3 (Please refer to Appendix I presents the result of an orthogonal (VARIMAX) rotation of the factor matrix underlying the quality management items. Based on the six-independent factor solution suggested by the eigenvalue pattern (i.e., greater than 1.0), 25 items were identified so that each of which loaded at least cleanly on only one of the six factors. A cutoff of 0.50 was used for item-scale selection. These factors accounted for over 78% of the variance in the quality management scale items. Following an inspection of the factor loadings, the six factors were subsequently labeled "Total management support," "customer focus," "education and training," "continuous improvement and innovation," "supply chain management," and "employee participation."
<table>
<thead>
<tr>
<th>Top management support</th>
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</thead>
<tbody>
<tr>
<td>TMS1</td>
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<td>TMS2</td>
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<td>TMS3</td>
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<td>TMS4</td>
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<thead>
<tr>
<th>Customer Focus</th>
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<tbody>
<tr>
<td>CF1</td>
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<td>CF2</td>
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<td>CF3</td>
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<tr>
<th>Education and Training</th>
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<td>EDT1</td>
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<td>EDT2</td>
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<td>EDT3</td>
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<td>EDT4</td>
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<table>
<thead>
<tr>
<th>Continuous improvement and innovation</th>
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<tbody>
<tr>
<td>CII</td>
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<td>CII2</td>
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<tr>
<th>Supply Management</th>
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<tbody>
<tr>
<td>SM1</td>
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<td>SM2</td>
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<td>SM3</td>
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<td>SM4</td>
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<tr>
<th>Employee Involvement</th>
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<tbody>
<tr>
<td>EEN1</td>
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<td>CII12</td>
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<td>CII14</td>
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<td>SM18</td>
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<td>EEN19</td>
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<td>EEN21</td>
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<td>EEN22</td>
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<td>EEN24</td>
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<tr>
<td>EEN25</td>
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</tbody>
</table>

Eigenvalue: 9.73, 3.99, 1.84, 1.60, 1.56, 1.09
Variance explained: 19.35, 14.78, 14.09, 11.40, 10.61, 8.67

\(^a\) A VARIMAX orthogonal rotation is performed on the initial factor matrix.
\(^b\) Factors derived from quality management

<table>
<thead>
<tr>
<th>EEN</th>
<th>TMS</th>
<th>SM</th>
<th>CII</th>
<th>CF</th>
<th>EDT</th>
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<tr>
<td>0.</td>
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</table>

Loadings above .50 are in boldface.
### Table 4
Results of the first-order and second-order confirmatory factor analysis of quality management

<table>
<thead>
<tr>
<th>Items</th>
<th>First-order Standardized loading</th>
<th>t-value</th>
<th>Second-order Standardized loading</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Total Quality Management-QM</strong></td>
<td></td>
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</tr>
<tr>
<td>Top management support</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Top managers’ commitment to post-implementation of quality management</td>
<td>.86</td>
<td>$.82*</td>
<td>.73</td>
<td>8.64</td>
</tr>
<tr>
<td>2. Top managers’ commitment to long-term investment on quality management</td>
<td>.91</td>
<td>15.65*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Top managers’ support of employee involvement in quality management implementation</td>
<td>.88</td>
<td>14.51*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Top managers’ strategic co-alignment of quality management with changes in market</td>
<td>.98</td>
<td>16.49*</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Customer Focus</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Center firm activities based on customer satisfaction</td>
<td>.84</td>
<td></td>
<td>.54</td>
<td>6.02</td>
</tr>
<tr>
<td>2. Customer satisfaction and expectation as a top goal</td>
<td>.83</td>
<td>11.52*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Importance of customers in top managers’ decisions</td>
<td>.88</td>
<td>12.25*</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Education and Training</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Top managers’ commitment in training employees in quality management</td>
<td>.96</td>
<td></td>
<td>.94</td>
<td>13.32</td>
</tr>
<tr>
<td>2. Top managers training in best conduct with employees and customers</td>
<td>.67</td>
<td>10.36*</td>
<td>13.27*</td>
<td></td>
</tr>
<tr>
<td>3. Employees knowledge about food industry</td>
<td>.95</td>
<td>15.66*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Managers’ commitment to provide employees essential needs at work</td>
<td>.76</td>
<td>13.27*</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Continuous improvement and innovation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Employees are encouraged to make suggestions about work condition improvements</td>
<td>.88</td>
<td></td>
<td>.70</td>
<td>8.23</td>
</tr>
<tr>
<td>2. Employees are encouraged to research to improve products and services</td>
<td>.75</td>
<td>11.21*</td>
<td>15.44 *</td>
<td></td>
</tr>
<tr>
<td>3. Manager’s consideration of suggestions for product/services improvement</td>
<td>.94</td>
<td></td>
<td>15.44 *</td>
<td></td>
</tr>
<tr>
<td><strong>Supply Management</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Coordination with critical supplier through information sharing</td>
<td>.88</td>
<td></td>
<td>.70</td>
<td>8.27</td>
</tr>
<tr>
<td>2. Enhance quality of suppliers post quality management implementation</td>
<td>.86</td>
<td>13.84*</td>
<td></td>
<td></td>
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<tr>
<td>3. Establish a win-win relation with suppliers</td>
<td>.78</td>
<td>11.76*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Strategic view on managing supply-chain</td>
<td>.86</td>
<td>13.83*</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Employee Involvement</strong></td>
<td></td>
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</tr>
<tr>
<td>1. Employee training and encouragement to participate in company programs</td>
<td>.57</td>
<td></td>
<td>.33</td>
<td>3.50</td>
</tr>
<tr>
<td>2. Creation of work improvement teams</td>
<td>.96</td>
<td>7.09*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Employees suggestions about improving supply-chain</td>
<td>.96</td>
<td>7.99 *</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Employees responsibility to inspect work outcome</td>
<td>.66</td>
<td>6.47*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Creation of quality circles to assist staff in problem solving</td>
<td>.70</td>
<td>6.71*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Employee participation in management quality programs</td>
<td>.75</td>
<td>7.00*</td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Establishing a reward program for novel suggestions by employees</td>
<td>.82</td>
<td>7.36*</td>
<td></td>
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</tbody>
</table>

*Fixed parameter
Chi-square = 670.02 (p < 0.001); df = 269; GFI = 0.93; AGFI = 0.88; RMSEA = 0.100.
* p < 0.001.

Learning organizations create knowledge to maintain internal efficiency and strategically competitive position by co-aligning to changes in the marketplace in a timely fashion. To measure organizational learning capability we used Structural Equation Modeling, organizational learning capability was operationalized as a second-order latent variable measured by four first-order factors, top executive commitment, system perspectives, organizational experimentations and knowledge transfer initiatives, (Jerez-Gomez, Cespedes-Lorente & Valle-Cabrera, 2005).

To further examine the underlying (or latent) relationships between the variables, we adopted the
principal components method of extraction to find the number of variables in the data file that accounts for as much variation in the original variables as possible; Initially, we selected 16 measurement items from a sample of 149 respondents, the measurement items were adopted from previous studies (Jerez-Gomez, Cespedes-Lorente & Valle-Cabrera, 2005). Respondents were asked to indicate their levels of agreement with descriptive statements using a 5-point Likert scale (range, 1 = strongly disagree to 5 = strongly agree). Table 5 shows the Kiser-Meyer-Olkin, and Bartlett test of sphericity utilized to measure four organizational learning dimensions, with each of the dimensions being measured by responses to several items. Results show (KMO > 0.818; $\chi^2 = 1843$, df, 120, sig 0.000). The results reasonably describe each set of items as being indicative of an underlying factor for learning at organizational level, which shows that there is relationship among four items of OL factor. The component including MC1-4, SP1-3, OEX1-4, KTI1-3. Table 6 shows OL scale items, Table 7 shows orthogonal (VARIMAX) rotation of the factor matrix and Table 8 shows the results of a second-order CFA and the scale reliability on organizational learning dimensions that reached statistical significance. This indicates that criteria had a significant correlation with dimensions, and that the scale had convergent validity (Anderson & Gerbing, 1988).

Table 5: KMO and Bartlett's Test of OL Variable

<table>
<thead>
<tr>
<th>Kaiser-Meyer-Olkin Measure of Sampling Adequacy</th>
<th>.818</th>
</tr>
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<tbody>
<tr>
<td>Bartlett's Test of Sphericity</td>
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<tr>
<td>Approx. Chi-Square</td>
<td>1843</td>
</tr>
<tr>
<td>Df</td>
<td>120</td>
</tr>
<tr>
<td>Sig</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Table 6 (Please refer to Appendix II) presents the item scales in organizational learning capability; Table 7 (Please refer to Appendix II) presents the result of an orthogonal
(VARIMAX) rotation of the factor matrix underlying organizational learning capability items. Based on the six-independent factor solution suggested by the eigenvalue pattern (i.e., greater than 1.0), 15 items were identified so that each of which loaded at least cleanly on only one of the four factors. A cutoff of 0.50 was used for item-scale selection. These factors accounted for over 75% of the variance in the organizational learning capability scale items. Following an inspection of the factor loadings, the four factors were subsequently labeled "management commitment," system perspectives," "organizational experiment," and "knowledge transfer initiative." After the initial component analysis we reduced the number of items to 15 which explained the highest variation in organizational learning.
## Table 6
### Organizational Learning Scale

<table>
<thead>
<tr>
<th>Learning Strategy and Capability</th>
<th>Management commitment</th>
</tr>
</thead>
<tbody>
<tr>
<td>MC1</td>
<td>Employee participation in management decision making</td>
</tr>
<tr>
<td>MC2</td>
<td>Invest in employee learning</td>
</tr>
<tr>
<td>MC3</td>
<td>Embracing change to adapt to changing business environment</td>
</tr>
<tr>
<td>MC4</td>
<td>Employee learning as a key success factor in company</td>
</tr>
<tr>
<td>MC5</td>
<td>Rewarding novel ideas</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Management commitment</th>
</tr>
</thead>
<tbody>
<tr>
<td>MC1</td>
</tr>
<tr>
<td>MC2</td>
</tr>
<tr>
<td>MC3</td>
</tr>
<tr>
<td>MC4</td>
</tr>
<tr>
<td>MC5</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>System perspective</th>
</tr>
</thead>
<tbody>
<tr>
<td>SP1</td>
</tr>
<tr>
<td>SP2</td>
</tr>
<tr>
<td>SP3</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Open experimentation</th>
</tr>
</thead>
<tbody>
<tr>
<td>OX1</td>
</tr>
<tr>
<td>OX2</td>
</tr>
<tr>
<td>OX3</td>
</tr>
<tr>
<td>OX4</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Knowledge Transfer Initiative</th>
</tr>
</thead>
<tbody>
<tr>
<td>KNT1</td>
</tr>
<tr>
<td>KNT2</td>
</tr>
<tr>
<td>KNT3</td>
</tr>
<tr>
<td>KNT4</td>
</tr>
</tbody>
</table>
Table 7
Factor Analysis of Organizational Learning Scales

<table>
<thead>
<tr>
<th>Derived Factors</th>
<th>MC</th>
<th>SP</th>
<th>OEX</th>
<th>KTI</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organizational Learning Capability</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MC1</td>
<td>.667</td>
<td>.286</td>
<td>.335</td>
<td>.132</td>
</tr>
<tr>
<td>MC2</td>
<td>.734</td>
<td>.174</td>
<td>.317</td>
<td>.158</td>
</tr>
<tr>
<td>MC3</td>
<td>.714</td>
<td>.351</td>
<td>.135</td>
<td>.222</td>
</tr>
<tr>
<td>MC4</td>
<td>.852</td>
<td>.059</td>
<td>.154</td>
<td>.098</td>
</tr>
<tr>
<td>MC5</td>
<td>.771</td>
<td>.295</td>
<td>.269</td>
<td>.080</td>
</tr>
<tr>
<td>SP6</td>
<td>.237</td>
<td>.850</td>
<td>.162</td>
<td>.035</td>
</tr>
<tr>
<td>SP7</td>
<td>.255</td>
<td>.797</td>
<td>.247</td>
<td>.168</td>
</tr>
<tr>
<td>OEX9</td>
<td>.199</td>
<td>.867</td>
<td>.226</td>
<td>.199</td>
</tr>
<tr>
<td>OEX10</td>
<td>.230</td>
<td>.290</td>
<td>.845</td>
<td>.053</td>
</tr>
<tr>
<td>OEX11</td>
<td>.186</td>
<td>.374</td>
<td>.789</td>
<td>.087</td>
</tr>
<tr>
<td>OEX12</td>
<td>.344</td>
<td>.052</td>
<td>.800</td>
<td>.246</td>
</tr>
<tr>
<td>KTI13</td>
<td>.166</td>
<td>.296</td>
<td>.162</td>
<td>.765</td>
</tr>
<tr>
<td>KTI14</td>
<td>.296</td>
<td>.164</td>
<td>.010</td>
<td>.838</td>
</tr>
<tr>
<td>KNTI15</td>
<td>-.097</td>
<td>-.199</td>
<td>-.221</td>
<td>-.726</td>
</tr>
</tbody>
</table>

| Eigenvalue | 7.57 | 1.76 | 1.50 | 1.24 |
| Variance explained | 22.79 | 18.57 | 18.26 | 15.89 |

* A VARMAX orthogonal rotation is performed on the initial factor matrix.

* Factors derived from organizational learning capability

<table>
<thead>
<tr>
<th>Factors</th>
<th>Cronbach’s alphas</th>
<th>Scales included</th>
</tr>
</thead>
<tbody>
<tr>
<td>MC</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>SP</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>OEX</td>
<td>0.</td>
<td>0.</td>
</tr>
<tr>
<td>KTI</td>
<td>0.</td>
<td>0.</td>
</tr>
</tbody>
</table>

* Loadings above .50 are in boldface.
Table 8
Results of the first-order and second-order confirmatory factor analysis of organization learning

<table>
<thead>
<tr>
<th>Items</th>
<th>First-order</th>
<th>Second-order</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Standardized loading</td>
<td>t-value</td>
</tr>
<tr>
<td><strong>Organizational Learning Capability</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Management commitment</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Employee participation in management decision making</td>
<td>.81</td>
<td>*/</td>
</tr>
<tr>
<td>2. Invest in employee learning</td>
<td>.78</td>
<td>10.36</td>
</tr>
<tr>
<td>3. Embracing change to adapt to changing business environment</td>
<td>.73</td>
<td>9.66</td>
</tr>
<tr>
<td>4. Employee learning as a key success factor in company</td>
<td>.77</td>
<td>10.33</td>
</tr>
<tr>
<td>5. Rewarding novel ideas</td>
<td>.86</td>
<td>11.89</td>
</tr>
<tr>
<td><strong>System perspective</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Employee knowledge about strategic direction of company</td>
<td>.83</td>
<td>*/</td>
</tr>
<tr>
<td>2. Divisional participation in company goals</td>
<td>.88</td>
<td>13.19</td>
</tr>
<tr>
<td>3. Communication among company divisions/ departments</td>
<td>.94</td>
<td>14.30</td>
</tr>
<tr>
<td><strong>Open experimentation</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Job expansion through creativity and experimentation</td>
<td>.85</td>
<td>*/</td>
</tr>
<tr>
<td>2. Adopting best practices in competitive field</td>
<td>.84</td>
<td>12.60</td>
</tr>
<tr>
<td>3. Considering expert views outside company to improve learning</td>
<td>.85</td>
<td>12.64</td>
</tr>
<tr>
<td>4. Creating a culture of accepting ideas generated by employees</td>
<td>.76</td>
<td>10.84</td>
</tr>
<tr>
<td><strong>Knowledge Transfer Initiative</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Discussion about shortcomings and mistakes at all levels</td>
<td>.82</td>
<td>*/</td>
</tr>
<tr>
<td>2. Discussions about ideas, programs and activities among employees</td>
<td>.83</td>
<td>10.43</td>
</tr>
<tr>
<td>3. Culture of teamwork</td>
<td>.44</td>
<td>5.14</td>
</tr>
<tr>
<td>4. Maintenance of work process documentation</td>
<td>.78</td>
<td>9.90</td>
</tr>
</tbody>
</table>

*/ Fixed parameter
Chi-square = 235.64 (p < 0.001); df = 100; GFI = 0.95; AGFI = 0.86; RMSEA = 0.095.
* p < 0.001.

Organizational innovation leads to reallocation of valued resources within organization toward new products and services, enhance corporations competitive position and overall performance (e.g., Hana, 2013; Luecke & Katz, 2003). To measure organizational innovation we used Structural Equation Modeling, organizational innovation was operationalised as a second-order latent variable measured by three first-order factors, product/ service innovation, performance innovation and overall organizational innovations, (Parjogo, Power & Sohal, 2004; Hung, Lien, Ya-Hui, Baiyin, Kuo & Ming, 2011). Table 9 shows Kiser-Meyer-Olkin, and Bartlett test of sphericity to measure 3 organizational innovation (INP) dimensions, with each of the dimensions being measured by responses to several items. Results show (KMO > 0.891; \( \chi^2 = 2.418E3 \), df, 136, Sig, 0.000). The results reasonably describe each set of items as being indicative of an underlying factor for organizational innovation. This shows that there is relationship among 3
items of INP factor. The component including PSI1-6, PRI1-6, OOI1-5. Table 10 shows INP scale items, Table 11 shows orthogonal (VARIMAX) rotation of the factor matrix and Table 12 shows the results of a second-order CFA and the scale reliability on organizational innovation dimensions that reached statistical significance. This indicates that criteria had a significant correlation with dimensions, and that the scale had convergent validity (Anderson & Gerbing, 1988).

**Table 9: KMO and Bartlett's Test of INO Variable**

<table>
<thead>
<tr>
<th>Kaiser-Meyer-Olkin Measure of Sampling Adequacy</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>.891</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bartlett's Test of Sphericity</th>
<th>Approx. Chi-Square</th>
</tr>
</thead>
<tbody>
<tr>
<td>Df</td>
<td>2.418E3</td>
</tr>
<tr>
<td>Sig</td>
<td>136</td>
</tr>
<tr>
<td></td>
<td>0.000</td>
</tr>
</tbody>
</table>

This study utilized principal components method to examine the underlying (or latent) relationships between the variables and find the number of variables in the data file that accounts for as much variation in the original variables. In this research we selected 17 measurement items from a sample of 149 respondents, the measurement items were adopted from previous studies (Parjogo, Power & Sohal, 2004; Hung, Lien, Ya-Hui, Baiyin, Kuo & Ming, 2011). Respondents were asked to indicate their levels of agreement with descriptive statements using a 5-point Likert scale (range, 1 = strongly disagree to 5 = strongly agree). Table 10 (Please refer to Appendix III) presents the item scales in organizational innovation; and Table 11 (Please refer to Appendix III) presents the result of an orthogonal (VARIMAX) rotation of the factor matrix underlying organizational innovation items. Based on the three-independent factor solution suggested by the eigenvalue pattern (i.e., greater than 1.0), 17 items were identified so that each of which loaded at least cleanly on only one of three factors. A cutoff of 0.50 was used for item-
scale selection. These factors accounted for over 74% of the variance in the organizational innovation scale items. Following an inspection of the factor loadings, the three factors were subsequently labeled "product/services initiatives," product innovation," and "overall organizational innovation."

Table 10
Organizational Innovation Scale

<table>
<thead>
<tr>
<th>Overall Organizational Innovation</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Product and service innovation</strong></td>
<td></td>
</tr>
<tr>
<td>PSI1 Higher rate of innovation in comparison to competitors</td>
<td></td>
</tr>
<tr>
<td>PSI2 Higher production improvement in comparison to competitors</td>
<td></td>
</tr>
<tr>
<td>PSI3 Faster acquisition of innovative ideas compare to competitors</td>
<td></td>
</tr>
<tr>
<td>PSI4 Knowledge and skill improvement through R&amp;D</td>
<td></td>
</tr>
<tr>
<td>PSI5 Production of products that better fit customer needs</td>
<td></td>
</tr>
<tr>
<td>PSI6 Introduction of new products to customers faster than competitors</td>
<td></td>
</tr>
<tr>
<td><strong>Performance innovation</strong></td>
<td></td>
</tr>
<tr>
<td>PRI1 Utilizing novel ideas to improve the product quality and speed of delivery to customers</td>
<td></td>
</tr>
<tr>
<td>PRI2 Utilizing quality resources in production process</td>
<td></td>
</tr>
<tr>
<td>PRI3 Flexibility in resources allocation</td>
<td></td>
</tr>
<tr>
<td>PRI4 Cost reduction through efficient resource allocation</td>
<td></td>
</tr>
<tr>
<td>PRI5 Adoption of human resources management</td>
<td></td>
</tr>
<tr>
<td>PRI6 Greater flexibility in organizational structure compare to competitors that allows innovation</td>
<td></td>
</tr>
<tr>
<td><strong>Overall organizational innovation</strong></td>
<td></td>
</tr>
<tr>
<td>OOI1 Best use of organizational resources to implement quality management</td>
<td></td>
</tr>
<tr>
<td>OOI2 Higher profitability after quality management implementation</td>
<td></td>
</tr>
<tr>
<td>OOI3 Unit cost reduction after implementation of quality management</td>
<td></td>
</tr>
<tr>
<td>OOI4 Financial improvement after quality management improvement</td>
<td></td>
</tr>
<tr>
<td>OOI5 Increased employee productivity after quality management implementation</td>
<td></td>
</tr>
</tbody>
</table>
Table 11
Factor Analysis of Organizational Innovation Scales

<table>
<thead>
<tr>
<th>Organizational Innovation</th>
<th>Derived Factors</th>
<th>PS(^b1)</th>
<th>PR(^b2)</th>
<th>OOI(^b3)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PS1</td>
<td></td>
<td>.760</td>
<td>.229</td>
<td>.303</td>
</tr>
<tr>
<td>PS2</td>
<td></td>
<td>.795</td>
<td>.219</td>
<td>.346</td>
</tr>
<tr>
<td>PS3</td>
<td></td>
<td>.818</td>
<td>.413</td>
<td>.180</td>
</tr>
<tr>
<td>PS4</td>
<td></td>
<td>.550</td>
<td>.339</td>
<td>.447</td>
</tr>
<tr>
<td>PS5</td>
<td></td>
<td>.781</td>
<td>.400</td>
<td>.218</td>
</tr>
<tr>
<td>PS6</td>
<td></td>
<td>.659</td>
<td>.246</td>
<td>.439</td>
</tr>
<tr>
<td>PR7</td>
<td></td>
<td>.459</td>
<td>.718</td>
<td>.155</td>
</tr>
<tr>
<td>PR8</td>
<td></td>
<td>.277</td>
<td>.730</td>
<td>.381</td>
</tr>
<tr>
<td>PR9</td>
<td></td>
<td>.141</td>
<td>.005</td>
<td>.121</td>
</tr>
<tr>
<td>PR10</td>
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</tr>
<tr>
<td>PR11</td>
<td></td>
<td>.337</td>
<td>.738</td>
<td>.253</td>
</tr>
<tr>
<td>PR12</td>
<td></td>
<td>.430</td>
<td>.757</td>
<td>.169</td>
</tr>
<tr>
<td>OOI13</td>
<td></td>
<td>.398</td>
<td>.169</td>
<td>.736</td>
</tr>
<tr>
<td>OOI14</td>
<td></td>
<td>.299</td>
<td>.261</td>
<td>.784</td>
</tr>
<tr>
<td>OOI15</td>
<td></td>
<td>.415</td>
<td>.298</td>
<td>.687</td>
</tr>
<tr>
<td>OOI16</td>
<td></td>
<td>.103</td>
<td>.249</td>
<td>.855</td>
</tr>
<tr>
<td>OOI17</td>
<td></td>
<td>.241</td>
<td>.162</td>
<td>.797</td>
</tr>
</tbody>
</table>

Eigenvalue 9.84 1.66 1.18
Variance explained 25.57 25.09 24.01

\(a\) A VARIMAX orthogonal rotation is performed on the initial factor matrix.

\(b\) Factors derived from organizational innovation

\(c\) Loadings above .50 are in boldface

Factors Cronbach’s alphas Scales included
---
\(^{b1}\) PS 0. 0.
\(^{b2}\) PR 0.
\(^{b3}\) OOI 0.

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Table 12
Results of the first-order and second-order confirmatory factor analysis of organization innovation

<table>
<thead>
<tr>
<th>Items</th>
<th>First-order Standardized loading</th>
<th>t-value</th>
<th>Second-order Standardized loading</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Overall Organizational Innovation</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Product and service innovation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Higher rate of innovation in comparison to competitors</td>
<td>.79</td>
<td></td>
<td>.92</td>
<td>9.88</td>
</tr>
<tr>
<td>2. Higher production improvement in comparison to competitors</td>
<td>.82</td>
<td>11.32</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Faster acquisition of innovative ideas compare to competitors</td>
<td>.94</td>
<td>13.55</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Knowledge and skill improvement through R&amp;D</td>
<td>.72</td>
<td>9.56</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Production of products that better fit customer needs</td>
<td>.92</td>
<td>13.21</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Introduction of new products to customers faster than competitors</td>
<td>.75</td>
<td>10.10</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Performance innovation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Utilizing novel ideas to improve the product quality and speed of delivery</td>
<td>.88</td>
<td></td>
<td>.85</td>
<td>10.25</td>
</tr>
<tr>
<td>2. Utilizing quality resources in production process</td>
<td>.80</td>
<td>12.61</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Flexibility in resources allocation</td>
<td>.68</td>
<td>9.72</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Cost reduction through efficient resource allocation</td>
<td>.78</td>
<td>11.86</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Adoption of human resources management</td>
<td>.81</td>
<td>12.86</td>
<td></td>
<td></td>
</tr>
<tr>
<td>6. Flexibility in orG-structure compare to competitors that allows innovation</td>
<td>.89</td>
<td></td>
<td>15.42</td>
<td></td>
</tr>
<tr>
<td>Overall organization innovation</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Best use of organizational resources to implement quality management</td>
<td>.77</td>
<td></td>
<td>.77</td>
<td>8.28</td>
</tr>
<tr>
<td>2. Higher profitability after quality management implementation</td>
<td>.88</td>
<td>11.74</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Unit cost reduction after implementation of quality management</td>
<td>.84</td>
<td>11.08</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Financial improvement after quality management improvement</td>
<td>.81</td>
<td>10.61</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Increased employee productivity after quality management implementation</td>
<td>.79</td>
<td></td>
<td>10.18</td>
<td></td>
</tr>
</tbody>
</table>

*Fixed parameter
Chi-square = 244.89 (p < 0.001), df = 116; GFI = 0.91; AGFI = 0.81; RMSEA = 0.086.
* p < 0.001.

Performance is the desired outcome within organizations, and it can be measured through multiple dimensions (Wheelen & Hunger, 2014). To measure organizational performance we utilized Structural Equation Modeling, organizational performance was operationalised as a second-order latent variable measured by four first-order factors, employee satisfaction, customer satisfaction, environmental performance, and social responsibility performance (Santos & Brito, 2012). We utilized Kiser-Meyer-Olkin, and Bartlett test of sphericity to measure four organizational performance dimensions, with each of the dimensions being measured by responses to several items. Table 13 show (KMO > 0.862; $\chi^2 = 1.971E3$, df, 120, Bartlett’s Test of Sphericity with significant of 0.000 (less than 0.05). Results reasonably describe each set of items as being indicative of an underlying factor for organizational performance. This shows that there is relationship among four items of OP factor. The component including EMS1-4,
CUS1-5, ENP1-3, SOP1-4. Table 14 shows OP scale items, Table 15 shows orthogonal (VARIMAX) rotation of the factor matrix and Table 16 shows the results of a second-order CFA and the scale reliability on organizational performance dimensions that reached statistical significance. This indicates that criteria had a significant correlation with dimensions, and that the scale had convergent validity (Anderson & Gerbing, 1988).

**Table 13: KMO and Bartlett's Test of OP Variable**

<table>
<thead>
<tr>
<th>Kaiser-Meyer-Olkin Measure of Sampling Adequacy</th>
<th>.862</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Bartlett's Test of Sphericity</strong></td>
<td></td>
</tr>
<tr>
<td><strong>Approx. Chi-Square</strong></td>
<td>1.971E3</td>
</tr>
<tr>
<td><strong>Df</strong></td>
<td>120</td>
</tr>
<tr>
<td><strong>Sig</strong></td>
<td>0.000</td>
</tr>
</tbody>
</table>

To measure organizational performance this study adopted 4 dimensions of, (1) employee satisfaction, (2) customer satisfaction, (3) environmental performance, and (4) social responsibility performance (Santos & Brito, 2012). We utilized principal components method to examine the underlying relationships between the variables and find the sub-set of variables in the data that accounts for as much variation in the organizational performance variable. This study selected 17 measurement items from a sample of 149 respondents, the measurement items were adopted from previous studies (Santos & Brito, 2012). Respondents were asked to indicate their levels of agreement with descriptive statements using a 5-point Likert scale (range, 1 = strongly disagree to 5 = strongly agree). Table 14 presents the item scales in organizational performance; and Table 15 presents the result of an orthogonal (VARIMAX) rotation of the factor matrix underlying organizational performance items. Based on the four-independent factor solution suggested by the eigenvalue pattern (i.e., greater than 1.0), 16 items were identified so that each of which loaded at least cleanly on only one of four factors. A cutoff of
0.50 was used for item-scale selection. These factors accounted for over 77% of the variance in the organizational performance scale items. Following an inspection of the factor loadings, the four factors were subsequently labeled "customer satisfaction," "employee satisfaction," and "environmental performance," and "social responsibility."

Table 14
Organizational Performance Scales

<table>
<thead>
<tr>
<th>Organizational Performance</th>
<th>Employee satisfaction</th>
</tr>
</thead>
<tbody>
<tr>
<td>EMS1</td>
<td>Employee satisfaction</td>
</tr>
<tr>
<td>EMS2</td>
<td>Ample remuneration for employees</td>
</tr>
<tr>
<td>EMS3</td>
<td>Reducing turnover after quality management implementation</td>
</tr>
<tr>
<td>EMS4</td>
<td>Reduction of absenteeism after quality management implementation</td>
</tr>
<tr>
<td>Customer satisfaction</td>
<td></td>
</tr>
<tr>
<td>CUS5</td>
<td>Customer satisfaction</td>
</tr>
<tr>
<td>CUS6</td>
<td>Introduction of new product and services</td>
</tr>
<tr>
<td>CUS7</td>
<td>Reduction of product defect returns after quality management implementation</td>
</tr>
<tr>
<td>CUS8</td>
<td>Strategies to maintain customer base</td>
</tr>
<tr>
<td>CUS9</td>
<td>Reducing customer complaints after quality management implementation</td>
</tr>
<tr>
<td>Environmental performance</td>
<td></td>
</tr>
<tr>
<td>ENP10</td>
<td>Consideration of environmental projects after implementation of quality management</td>
</tr>
<tr>
<td>ENP11</td>
<td>Reducing production pollution after quality management implementation</td>
</tr>
<tr>
<td>ENP12</td>
<td>Reducing complaints about environmental pollution</td>
</tr>
<tr>
<td>Social responsibility performance</td>
<td></td>
</tr>
<tr>
<td>SOR13</td>
<td>Equal opportunity for employment of minorities</td>
</tr>
<tr>
<td>SOR14</td>
<td>Cultural events sponsored by company</td>
</tr>
<tr>
<td>SOR15</td>
<td>Social responsibility of company</td>
</tr>
<tr>
<td>SOR16</td>
<td>Reducing litigations by employees</td>
</tr>
</tbody>
</table>
**Table 15**

Factor Analysis of Organizational Performance Scales

<table>
<thead>
<tr>
<th>Derived Factors&lt;sup&gt;c&lt;/sup&gt;</th>
<th>CUS&lt;sup&gt;b1&lt;/sup&gt;</th>
<th>EMS&lt;sup&gt;b2&lt;/sup&gt;</th>
<th>SOR&lt;sup&gt;b3&lt;/sup&gt;</th>
<th>ENP&lt;sup&gt;b4&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organizational Performance&lt;sup&gt;b&lt;/sup&gt;</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>EMS1</td>
<td>.306</td>
<td>.731</td>
<td>.288</td>
<td>.279</td>
</tr>
<tr>
<td>EMS2</td>
<td>.211</td>
<td>.810</td>
<td>.297</td>
<td>.210</td>
</tr>
<tr>
<td>EMS3</td>
<td>.301</td>
<td>.844</td>
<td>.195</td>
<td>.120</td>
</tr>
<tr>
<td>EMS4</td>
<td>.400</td>
<td>.689</td>
<td>.089</td>
<td>.319</td>
</tr>
<tr>
<td>CUS5</td>
<td>.668</td>
<td>.436</td>
<td>.285</td>
<td>-.016</td>
</tr>
<tr>
<td>CUS6</td>
<td>.819</td>
<td>.133</td>
<td>.198</td>
<td>.226</td>
</tr>
<tr>
<td>CUS7</td>
<td>.680</td>
<td>.090</td>
<td>.542</td>
<td>.095</td>
</tr>
<tr>
<td>CUS8</td>
<td>.797</td>
<td>.337</td>
<td>.088</td>
<td>-.038</td>
</tr>
<tr>
<td>CUS9</td>
<td>.876</td>
<td>.219</td>
<td>.139</td>
<td>.138</td>
</tr>
<tr>
<td>ENP10</td>
<td>.163</td>
<td>.157</td>
<td>.202</td>
<td>.836</td>
</tr>
<tr>
<td>ENP11</td>
<td>.078</td>
<td>.543</td>
<td>.158</td>
<td>.680</td>
</tr>
<tr>
<td>ENP12</td>
<td>.024</td>
<td>.184</td>
<td>.306</td>
<td>.784</td>
</tr>
<tr>
<td>SOR13</td>
<td>.310</td>
<td>.362</td>
<td>.724</td>
<td>.203</td>
</tr>
<tr>
<td>SOR14</td>
<td>.218</td>
<td>.014</td>
<td>.738</td>
<td>.307</td>
</tr>
<tr>
<td>SOR15</td>
<td>.015</td>
<td>.470</td>
<td>.689</td>
<td>.173</td>
</tr>
<tr>
<td>SOR16</td>
<td>.270</td>
<td>.267</td>
<td>.756</td>
<td>.196</td>
</tr>
</tbody>
</table>

Eigenvalue | 8.20 | 1.90 | 1.30 | 1.05 |
Variance explained | 22.62 | 22.06 | 18.32 | 14.36 |

<sup>a</sup> A VARIMAX orthogonal rotation is performed on the initial factor matrix.

<sup>b</sup> Factors derived from organizational performance.

<sup>c</sup> Loadings above .50 are in boldface.
Table 16
Results of the first-order and second-order confirmatory factor analysis of organizational performance

<table>
<thead>
<tr>
<th>Items</th>
<th>First-order standardized loading</th>
<th>t-value</th>
<th>Second-order standardized loading</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Organizational Performance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Employee satisfaction</td>
<td>.86</td>
<td>/</td>
<td>.91</td>
<td>10.88</td>
</tr>
<tr>
<td>1. Employee satisfaction</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Ample remuneration for employees</td>
<td>.87</td>
<td>14.12</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Reducing turnover after quality management implementation</td>
<td>.88</td>
<td>14.37</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Reduction of absenteeism after quality management</td>
<td>.83</td>
<td>12.97</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Customer satisfaction</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Customer satisfaction</td>
<td>.81</td>
<td>/</td>
<td>.72</td>
<td>8.00</td>
</tr>
<tr>
<td>2. Introduction of new product and services</td>
<td>.80</td>
<td>10.91</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Reduction of product defect returns after quality</td>
<td>.75</td>
<td>10.03</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Strategies to maintain customer base</td>
<td>.82</td>
<td>11.41</td>
<td></td>
<td></td>
</tr>
<tr>
<td>5. Reducing customer complaints after quality management</td>
<td>.89</td>
<td>12.65</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Environmental performance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Consideration of environmental projects after</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>quality management implementation</td>
<td>.74</td>
<td>/</td>
<td>.75</td>
<td>7.41</td>
</tr>
<tr>
<td>2. Reducing production pollution after quality management</td>
<td>.85</td>
<td>9.31</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Reducing complaints about environmental pollution</td>
<td>.75</td>
<td>8.56</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Social responsibility performance</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Equal opportunity for employment of minorities</td>
<td>.89</td>
<td>/</td>
<td>.83</td>
<td>10.04</td>
</tr>
<tr>
<td>2. Cultural events sponsored by company</td>
<td>.67</td>
<td>9.15</td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Social responsibility of company</td>
<td>.73</td>
<td>10.54</td>
<td></td>
<td></td>
</tr>
<tr>
<td>4. Reducing litigations by employees</td>
<td>.82</td>
<td>12.62</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

*a Fixed parameter
Chi-square = 232.06 (p < 0.001), df = 100; GFI = 0.93; AGFI = 0.84; RMSEA = 0.094.

Table 17
Results of structural equation modeling- Model I

<table>
<thead>
<tr>
<th>Items</th>
<th>Standardized regression weight</th>
<th>Standardized bias</th>
<th>t-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Quality management→ Organizational learning</td>
<td>0.95</td>
<td>0.08</td>
<td>13.41</td>
</tr>
<tr>
<td>Quality management→ Innovation performance</td>
<td>0.91</td>
<td>0.08</td>
<td>12.41*</td>
</tr>
<tr>
<td>Quality management→ Organizational performance</td>
<td>0.43</td>
<td>0.08</td>
<td>1.13</td>
</tr>
<tr>
<td>Quality management→ Education and training</td>
<td>0.90</td>
<td>0.08</td>
<td>14.20*</td>
</tr>
<tr>
<td>Quality management→ Total management support</td>
<td>0.72</td>
<td>0.08</td>
<td>10.41*</td>
</tr>
<tr>
<td>Quality management→ Continuous improvement</td>
<td>0.61</td>
<td>0.08</td>
<td>8.60*</td>
</tr>
<tr>
<td>Quality management→ Supply management</td>
<td>0.55</td>
<td>0.08</td>
<td>7.67*</td>
</tr>
<tr>
<td>Quality management→ Customer focus</td>
<td>0.45</td>
<td>0.08</td>
<td>6.29*</td>
</tr>
<tr>
<td>Quality management→ Employee involvement</td>
<td>0.41</td>
<td>0.08</td>
<td>6.71*</td>
</tr>
<tr>
<td>Organizational learning→ Management commitment</td>
<td>0.84</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Organizational learning→ System perspective</td>
<td>0.71</td>
<td>0.08</td>
<td>10.34*</td>
</tr>
<tr>
<td>Organizational learning→ Organizational experiment</td>
<td>0.66</td>
<td>0.08</td>
<td>9.31*</td>
</tr>
<tr>
<td>Organizational learning→ knowledge transfer</td>
<td>0.83</td>
<td>0.08</td>
<td>8.71*</td>
</tr>
<tr>
<td>Innovation performance→ Product/service</td>
<td>0.92</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Innovation performance→ Process innovation</td>
<td>0.78</td>
<td>0.08</td>
<td>12.24*</td>
</tr>
<tr>
<td>Innovation performance→ Overall organizational innovation</td>
<td>0.79</td>
<td>0.08</td>
<td>12.57*</td>
</tr>
<tr>
<td>Organizational performance→ Employee satisfaction</td>
<td>0.75</td>
<td>/</td>
<td>/</td>
</tr>
<tr>
<td>Organization Performance→ Customer satisfaction</td>
<td>0.59</td>
<td>0.08</td>
<td>7.79*</td>
</tr>
<tr>
<td>Organizational performance→ Environmental performance</td>
<td>0.63</td>
<td>0.08</td>
<td>8.57*</td>
</tr>
<tr>
<td>Social organizational responsibility</td>
<td>0.93</td>
<td>0.08</td>
<td>13.16*</td>
</tr>
</tbody>
</table>
Procedures and Design

Quality management is an integrated organizational strategy (e.g., Joiner, 2006), as such we explored two models for our design. The path diagrams in the model I (Figure 5) centers attention on three fundamental relationships. In model I we explored the relationship between quality management and organizational performance mediated by organizational learning and innovations.

Analysis and Results

We calculated a variety of analyses to explore the hypotheses. Prior to testing of our hypotheses, normal distribution of data was examined using Kolmogrov-Smirnov (KS) test. The assumption of normality is important when drawing accurate and reliable information about population under study and in constructing models and reference intervals for variables (Royston, 1991; Field, 2009). Four variables in our study, quality management, learning capability, innovation, and organizational performance were tested for normality of distribution assumption, using Kolmogrov-Smirnov test. Results revealed for each variable under study, (Quality management, n = 149, mean = 3.26, sd = .60, KS-Z = .715, Sig, .68); (Organization learning, n = 149, mean = 3.37, sd = .65, KS-Z = .72, sig, .67); (Innovation, n = 149, mean = 3.34, sd = .67, KS-Z = .92, sig, 3.58); (Organization performance, n = 149, mean = 3.34, sd = .66, KS-Z = .69, sis, .72). Means and standard deviations for four variables show that data are normally distributed. LISREL 8.8 employs iterative numerical procedures, commonly used in other path analysis computer programs, to obtain final solutions. The iterative procedure stops when the values for the parameters in two consecutive iterations differ by less than some preset criterion. The LISREL program provided several model fit measures including root mean square
error of approximation (RMSEA), normed fit index (NFI), adjusted goodness fit index (AGFI), and normed chi-square. Browne and Cudeck (1993) suggest that a value of 0.05 of RMSEA indicates a close fit of the model to the population and that values up to 0.08 represent reasonable errors of approximation in the population. NFI measure compares the proposed path model and a base model which specifies no correlation between the variables. It represents a good fit when the value of NFI is greater than 0.90. AGFI and normed chi-square indicate whether a proposed model may be over-fitted or is not yet truly representative of the observed data and thus need improvement. A recommended acceptance level of AGFI is a value greater than 0.90. Normed chi-square must be between 1.0 and 2.0 to accept the model.

**Quality management.** Results of path analysis are shown in Figure 1 and the correlation matrix for these scales appears in Table A. Paths coefficients and corresponding t-values the fit statistics for quality management are shown in Figure 1. Fit statistics show RMSEA of 0.100, GFI measure of .93, AGFI measure of 0.88, and normed chi-square of 2.49. These estimates indicate a good fit of the model, the coefficient is significant at the 0.05 level if its t-value is greater than 1.96. Results are indicative of six dimensions as integral part of quality management practice and in their highest priority to top management are education and training (EDT, B = .94), top management support (TMS, B = .73), continuous improvements (CII, B = .70), management supplier relations (SM, B = .70), customer focus (CF, B = .54), and employee involvements (EEN, B = .33). Further analysis of variables within the subset of quality management dimension show the priorities of top managements seem to be based on education and training (EDT, B = .94), which is critical factor in employee and organizational learning and innovations (e.g., Schumpeter, 1934; Hana, 2012). Similarly, Schumpeter (1934) argued that knowledgeable human capital tends to be a key factor to innovative ideas. Analysis
of the second-order latent variable measured by four first-order factors shown in Figure 1, indicated that top executives strategically emphasize on higher employee learning through education and training, not only for innovative ideas (EDT1, B = .96), but also for the implementations of quality management in the long-term (TMS1, B = .91). Top executives commitment to higher education (EDT1, B = .96), and skilled employee teams (EEN2, B = .96) facilitates the implementation of continuous improvements within organization (EEN3, B = .96). Furthermore, strategically, in the long-term top executives are committed to investing in human resources within quality management practices (TMS2, B = .91). Such long-term investment enables the organization to timely adapt to industry environment (TMS4, B = .93), acquire valued resources (SM2, B = .96), accumulate knowledge about the industry (EDT3, B = .95) and meet customer expectations (CF3, B = .88; CF1, B = .84; CF2, B = .83).

Organizational learning capability. Fit statistics for organizational learning show RMSEA of 0.095, GFI measure of .95, AGFI measure of 0.86, and normed chi-square of 2.35. Paths coefficients and corresponding t-values the fit statistics for organizational learning are shown in Figure 2. These estimates indicate a good fit of the model, the coefficient is significant at the 0.05 level if its t-value is greater than 1.96. Results of four dimensions of organizational learning show executive priorities on management commitment (MC, B = .88), open experimentations (OEX, B = .80), systems thinking (SP, B = .72) and knowledge transfer (KTI, B = .63) as integral part of organizational learning. Further analysis of organizational learning sub-set variables reveals that higher commitment of top management to employees learning capability (MC1, B = .88) and involvement in management decision making processes (MC4, B = .88) can lead to cross-functional communication (SP3, B = .94) and co-alignment of employee efforts with strategic goals within the company ((SP1, B = .88). Furthermore, the learning
process promotes new way of doing existing jobs (OEX1, B = .85), selection of best practices in the industry (OEX2, B = .84; OEX, B = .85) and creation of culture of sharing information (OEX4, B = .76; KTI2, B = .83).

**Organizational innovation.** Fit statistics for organizational innovations show RMSEA of 0.086, GFI measure of .91, AGFI measure of 0.81, and normed chi-square of 2.11. The estimates indicate a good fit of the model, the coefficient is significant at the 0.05 level if its t-value is greater than 1.96. Paths coefficients and corresponding t-values the fit statistics for innovations are shown in Figure 3. Results of three dimensions of organizational innovations reveal the executive priorities seem to be based on product and service innovation (PSI, B = .92), process innovation (PRI, B = .85) and overall organizational innovation (OOI, B = .77).

Analysis of the sub-set variables within each dimension showed that executives place strategic importance on the first mover advantage and speed (PSI3, B = .94), higher allocation of resources on research and development (PSI2, B = .82), with which products and services are presented to market (e.g., Hoskisson, Hitt & Ireland, 2014). Moreover, the first mover advantage presents products and services that match the customer expectations (PSI5, B = .92; PRI1, B = .88). Implementation of quality management enables the executives to adopt a more flexible organizational structure (PRI6, B = .89; PRI5, B = .81), to capitalize on new innovations and enhance profitability (OOI2, B = .88), reduce process costs associated with the creation of new products and services (OOI3, B = .84) and better allocation of human (OOI5, B = .79) and financial resources (OOI4, B = .81) compare to other rivals in the industry (PSI2, B = .82; PRI6, B = .89).

**Organizational performance.** Paths coefficients and corresponding t-values the fit statistics for organizational performance are shown in Figure 4. Fit statistics for organizational
performance indicated RMSEA of 0.094, GFI measure of .93, AGFI measure of 0.84, and normed chi-square of 2.32. These estimates indicate a good fit of the model, the coefficient is significant at the 0.05 level if its t-value is greater than 1.96. Using Structural Equation Modelling, organizational performance was operationalised as a second-order latent variable measured by four first-order factors of employee satisfaction, corporate social responsibility, environmental performance, and customer satisfaction. According to findings four dimensions of organizational performance are integral part the criteria and executive priorities are concentrated on employee satisfaction (EMS, B = .91), corporate social responsibility (SOP, B = .83), environmental performance (ENP, B = .75) and customer satisfaction (CUS, B = .72).

Analysis of the second-order latent variable measured by four first-order factors revealed that executives place strategic importance on employee retention and reducing the employee intent to leave organization (EMS3, B = .88). Employee satisfaction (ems1, B= .86) is enhanced by better remunerations (EMS2, B = .87) that leads low absenteeism (EMS4, B = .83) after quality management implementation (e.g., Yue, Ooi & Keong, 2010). Further analysis of the first order factors revealed that organizational policies (CUS4, B = .82) are focused on reduction of customer complaints about defected products (CUS5, B = .89; CUS3, B= .75), and increasing new products and services to market (CUS2, B = .80). Top executives were also cognizant about company’s reputation by reducing the negative externalities caused by production pollution (ENP3, B = .85; ENP3, B = .75, ENP1, B = .74). As a socially responsible company, top executive centered attention on legal environment in relation to company’s operations (SOP4, B = .82), equal opportunity employment (SOP1, B = .89) and getting involve with community through cultural projects (SOP3, B = .73; SOP2 B = .67).
Model I, shown in Figure 5. In model I we tested the proposed research hypotheses and structural model utilizing structural equation modeling. The LISREL program 8.8 provided several model fit measures including root mean square error of approximation (RMSEA), (AGFI), and normed chi-square. Browne and Cudeck (1993) suggest that a value of 0.05 of RMSEA indicates a close fit of the model to the population and that values up to 0.08 represent reasonable errors of approximation in the population. AGFI and normed chi-square indicate whether a proposed model may be over-fitted or is not yet truly representative of the observed data and thus need improvement. A recommended acceptance level of AGFI is a value greater than 0.90. Normed chi-square must be between 1.0 and 2.0 to accept the model.

**Model I results.** Table 17 shows quality management directly affected innovation performance \( (B2 = 0.91, p < .05) \) and organizational learning \( (B1 = .95, p < .05) \). These results indicate as an implementation of integrated quality management strategy generates a cross-functional synergy which enhances organizational learning and innovation of new products and services. These results support Hypotheses 1 and Hypotheses 2, and are congruent with previous studies (e.g., Bohmer & Edmondson, 2001; Barrow, 1993; Hung, Lien, Yang, Wud & Kuo, 2010).

**Hypothesis 1:** Quality management is positively associated with organizational learning.

**Hypothesis 2:** Quality management is positively associated with organizational innovation.

Findings reveal that organizational learning is positively associated with overall performance \( (B = .60, p < .05) \). Top management commitment to long-term learning process through knowledge sharing and human capital investment can create an environment that permits
open experimentation with new ideas. As such, new way of doing things cross-functionally and new products and services enhances overall organizational performance. Results indicated that management is committed (B = .84, p < .05) to knowledge generation (B = .84, p < .84) cross functionally (B = .71, p < .71). As such, employees’ learning is enhanced through interactions and experimentation of novel way of doing things. Furthermore, our findings show a positive and significant relationship between innovations and organizational performance (B = .62, p < .05). As shown in Model I, Figure 5, management priority is place on being the first mover strategy in introducing the new products and services within organization (B = .92, p < .05). The first mover advantage in the introduction of new products and services enhances overall performance and enables organization to maintain a competitive position within the market segment and gain above average returns (e.g., Hoskisson, Hitt & Ireland, 2015). These findings supported Hypothesis 1a and Hypothesis 2a.

**Hypothesis 1a:** Learning performance is positively associated with organizational performance.

**Hypothesis 2a:** Organizational innovation is positively associated with learning performance.

Findings also show that employee and management education and training are integral part of quality management. This finding is congruent with strategic views of top executives’ support for long-term investments in quality management training process (B = .90, p < .05), and employees’ involvement in quality decisions (e.g., Luthans, 1995). Implementing quality management enables organizations to utilize employees’ tacit and explicit knowledge to co-align internal processes and products to changing environment (B = .72, p < .05). Findings in Model I also indicates that even though quality management is positively associated with organizational
performance (B = .43), the relationship is not significant at (p < .05) level. This may be attributed to our non-financial measure of performance variable in our study. Hence, results did not support Hypothesis 3.

**Hypothesis 3:** *Quality management is positively associated with organization performance.*

Our findings were incongruent with past research (e.g., Kaynak, 2003; Jaafre and Ai-abedallat, 2012). The results revealed that TQM has a weak direct association with organizational performance. We attribute our results, partly, due to qualitative measures of the performance in this study.

**Concluding Remarks**

Results of our research imply that the relationship between TQM practices and organizational performance tends to be contingent on organizational learning and innovations. The interactions among members of the organization allow both implicit and explicit learning through exploration and experimentation with novel way of doing things. TQM implementation allows a greater malleable structural design which enables the organization to absorb new knowledge into continuous process improvement and innovation of new products. Our findings showed that higher organizational learning and innovation of new products and services have a positive association with organizational performance. Our findings revealed that TQM has a weak association with performance. Our non-significant findings on TQM-performance relationship may be due to untangling major components of the TQM in our study. We focused on the mediating effects of organizational learning and innovations on the relationship between TQM and performance. The theoretical foundation of TQM tends to be based on an integrated set of
compatible parts and culture (e.g., Kujala & Lillrank, 2004). Hence, future researchers may examine the moderating effects of organizational learning and innovation on the relationship between performance and TQM.

References


APPENDIX I

Conceptual Model I: Mediating effects of organizational learning and innovations on the relationship between TQM and performance.
Appendix II
Path coefficients for primary and latent variables

Chi-Square=247.24, df=114, P-value=0.00000, RMSEA=0.089
Non-profit organizations account for 5.4% of the U.S. gross domestic product, an equivalent of $888 billion in 2012. In addition to providing 11.4 million jobs, non-profits managed 62.6 million volunteers who contributed 7.7 billion hours of service. Although non-profit organizations have some similarities to for-profit organizations, there are critical differences that require different management practices. The intent of this study is to understand how operational processes can be designed and managed to accommodate and leverage the distinct characteristics of non-profit organizations to maximize their performance.

Two distinct characteristics of non-profits that separate them from for-profit organizations are their objective (which by definition is not profit maximizing, and thus mission driven) and their use of volunteer labor. In fact, many non-profit organizations would claim that the use of volunteers in their processes is integral to their mission. Thus, a critical operational question is how to incorporate volunteer labor into the processes of the organization to best achieve the goals of the organization.

Specifically, the following research questions motivate our study: 1) What factors drive the tradeoff between non-profit productivity and volunteer engagement? Using the answer to question 1), we then ask, 2) What are the optimal job design and work allocation for volunteers (i.e., what is the optimal complexity of tasks volunteers perform and what proportion of the total work should be performed by volunteers)?

To study these questions, we developed a model of non-profit organizations, where volunteers have diverse skills and motivations for volunteering, and the organization strives to maximize its social impact given its financial and resource constraints. The key tension that drives the model is non-profit productivity vs. volunteer engagement. On one hand, volunteers are generally less productive than paid employees. But on the other hand, they are low-cost labor and successful volunteer engagement is a source of goodwill in the community that helps bring in donations.

Key insights from the model include: If volunteers are strategic (able to anticipate that they may not be successfully engaged), then the nonprofit would increase volunteer work allocation. Increasing job complexity can increase volunteer engagement without sacrificing total productivity. In addition, we are in the process of gathering data from non-profit organizations to test the findings of our model.
Quality Formation Process in Professional Services: A Simulation Study

Short Abstract

This study investigates how quality is formed in professional services using a simulation approach. Professional services can be characterized by a series of service sessions in an extended time frame. A service is defined in terms of a number of service attributes. We simulate the service attributes, which are produced, and experienced by customers in periods. We collect data on quality levels during a simulation and aggregate the data at the end, drawing an overall, dynamic picture of the quality from organization’s and customer’s perspectives.

Long Abstract

This study investigates how quality is formed in professional services using a simulation approach. Professional services can be characterized by a series of service sessions in an extended time frame. Examples include classes in education, patient care/treatments in hospitals/clinics, visits to the attorney in a lawsuit, and consultations with experts in a project. The professional services are different from other services in which a single transaction occurs in random intervals, such as trying a new restaurant, visiting the doctor due to flu, attending a presentation, asking a question to a lawyer or an expert.

In assessing service quality, literature suggests primarily to use customer satisfaction based measures such as SERVQUAL (Parasuraman et al., 1985), or measures based on conformance to service specifications (Deming, 1986; Powell, 1995). Lately, some attempts made to combine customer perceptions, satisfaction, and conformance to specifications in a single framework (Golder et al, 2012). These attempts are based on a process view in the formation of quality, with sub processes such as designing product features and specifications, production, customer perceptions, evaluation and judgement on the service.

Golder et al. (2012)’s integrating framework of quality formation describes a dynamic system with flow items and feedback links (Figure 1). According to this framework, a service is defined in terms of a number of service attributes, such as teacher qualifications and skills, class size, physician’s time and care for patients, psychiatrist’s communications skills. These attributes are designed, produced, delivered by the company; consumed, experienced, perceived, and evaluated by the customer. An overall judgement of the quality of the service is so formed by the customer. This formation of quality does not happen in one service encounter. It evolves over the cycles of service delivery sessions. In the beginning, a customer with a certain mindset and expectation from the service may leave the service with a totally different mindset, impression and a satisfaction level resulting from being exposed to the service in cycles.

In professional services like education or healthcare, the service is offered in cycles requiring student’s or patient’s close and continuous cooperation or participation for the successful delivery of the service. In this sense, customers are considered “co-producing” individuals in the delivery of the service. Due to this active involvement of the customer in the service, formation of the quality in customer’s mind is determined in a dynamic fashion, involving organization’s input and output, customer’s input and output, all entangled, interactive and dynamically changing each other through service cycles.

In this study, we use a simulation approach to model the quality formation process as described mainly by Golder et. (2012) in general terms. Based on this general framework, we define specific relationships and behaviors in simple equations, attempting to capture essential behavior in professional services. The simulation model assumes that N customers arrive at the organization, one person at a time, with varying expectations from the service. The professional service is defined by three key attributes: an
attribute which is totally produced by the organization employee, 2) an attribute produced by customer only, and 3) an attribute co-produced by both employee and the customer. A co-produced attribute’s performance is formulated as: \( S_t = a O_t + (1-a) C_t \). Coefficient \( a \) is the co-production ratio, \( O_t \) is the organization employee’s performance, \( C_t \) is the customer’s performance, and finally \( S_t \) is the total performance of the co-produced attribute. Performance is quantified between 1 and 100, 1 being the lowest setting, and 100 is the highest setting. Target values (i.e. service specifications) of the attribute settings are determined by scenarios in the beginning. For example, in “striving for the perfect service” scenario, all target attribute values are set to 100. In the service production stage, the service produces these attributes closer to the target settings in each period on a random basis. Random numbers are generated around the attribute target values based on Beta distribution. Simulation for customer \( n \) is run for \( T \) periods. At the end, next customer with a different performance expectation from the attributes is taken to the service. As for performance measures, “quality states” data is collected on the following, as seen in Table 1:

1. What is designed (target values \( S^* \)) and what is produced \( (S_t) \),
2. What is expected by the customer \( (E_t) \) and what is delivered \( (S_t) \),
3. What is perceived by the customer \( (P_t) \) and what is delivered \( (S_t) \),

When the simulation is complete, the data is summarized/aggregated to reflect the following:

1. What is expected by customer overall and what is the overall perception/experience of the service delivered,
2. What is the overall customer satisfaction level from the service.

Table 1. Quality assessment measures used in this study

<table>
<thead>
<tr>
<th>Quality Measure</th>
<th>Golder et al (2012)</th>
<th>This Study</th>
<th>Measurement Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Produced Attribute Quality</td>
<td>( S_t / S^* )</td>
<td>( S_t / S^* )</td>
<td>Periodic</td>
</tr>
<tr>
<td>Experienced Attribute Quality</td>
<td>( S_t / E_t )</td>
<td>( S_t / E_t )</td>
<td>Periodic</td>
</tr>
<tr>
<td>Expected Attribute Quality</td>
<td>( P_t / E_t )</td>
<td>( P_t / E_t )</td>
<td>Periodic</td>
</tr>
<tr>
<td>Perceived Attribute Quality</td>
<td>( P_t / S_t )</td>
<td>( P_t / S_t )</td>
<td>Periodic</td>
</tr>
<tr>
<td>Evaluated Aggregate Quality</td>
<td>( \sum P_t / \sum E_t )</td>
<td>( \sum P_t / \sum E_t )</td>
<td>When service completed</td>
</tr>
<tr>
<td>Perceived Aggregate Quality</td>
<td>( \sum P_t / \sum S_t )</td>
<td>( \sum P_t / \sum S_t )</td>
<td>When service completed</td>
</tr>
<tr>
<td>Produced Aggregate Quality</td>
<td>( \sum S_t / \sum S^* )</td>
<td>( \sum S_t / \sum S^* )</td>
<td>When service completed</td>
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</tbody>
</table>

**Conclusion**

Professional services constitute a significant proportion in services. Due to its special nature involving high customer contact, co-production and service delivery in extended periods, assessing quality should be carried out differently from other services. As literature suggests, quality is formed over service delivery cycles which require a continuous, dynamic quality assessment to observe the evolution of quality from the perspective of customers, as well as the company. One possible benefit of this dynamic assessment is timely feedback and corrective actions when the service is not delivering its best to match the expectations of the customers.

Our unique simulation approach to study quality formation in professional services assists the analyst to try out different service and customer conditions as service is delivered, and observe the behavior of the key quality indicators of the service. Finally, these key indicators are aggregated over the entire
simulation run, resulting an overall picture of the quality from the company’s and customer’s perspectives. One disadvantage of the simulation approach used here is that it attempts to capture complex cognitive processes (motivation, knowledge, perceptions, etc.) by simple filters based on formulas with weights. Nevertheless, the study should shed some initial light in this area, and lead to empirical studies involving actual customers.

Figure 1. Quality Formation Process (Adapted from Golder et al. 2012)
References:


Decentralizing Marketing of Academic Programs Using Social Media

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Many higher education institutions utilize centralized marketing and communication efforts to ensure consistency among the promotion of the institution as a whole and the academic units. Traditionally, academic programs are not equipped to sustain their own unique marketing needs and mostly rely on their institutions’ marketing divisions to handle such tasks. Although this allows for a consistent and well-controlled message throughout colleges and universities, it also brings challenges where the authenticity of each academic program may be diminished along the chain of command. Growth in mobile online access and social media use supports potential and current students eager for real-time social engagement along with an opportunity for departments to reach specific audiences using online channels. This study discusses how academic programs can utilize social media as a marketing tool using their existing resources such as faculty, students, and staff. A case study of Roger Williams University’s Construction Management program is presented along with 2 years of data collected from the program’s Facebook page. Results of this study include a set of best social media management practices for academic programs.
How to Respond When a Consumer Complains About Your Firm Online

The goal of the current study is to examine how firms should respond to online complaints and whether their responses should be tailored to who is reading the complaint (i.e., the original writer of the complaint or a reader of the complaint). Three key response actions have been discussed in the literature: compensation, empathetic response, and information (e.g., Lazare 2004). Compensation refers to awarding something (typically a discount, refund, coupon, or free upgrade) to a consumer as a recompense for their loss or suffering. To express empathy a service provider may identify how the customer is feeling and communicate this to the customer (e.g., “I understand that you are angry.”). Explanation/information refers to explaining what failure occurred and why it happened. When creating a response, firms may vary the use of these strategies (and their strength) to “frame” or tone their message as “affective” or “cognitive” (Santelli, Struthers, & Eaton 2009). An affective response refers to one in which the provider is focused on the consumer and the consumer’s emotions. This response will involve high levels of empathy. A cognitive response focuses on the process that lead to the failure and the steps that will be taken to correct it. Therefore, it involves the strategies of compensation and explanation/information.

Many factors affect whether a consumer will prefer an affectively or a cognitively framed response to a complaint such as the severity of the failure, the type of failure, or the emotional state of the consumer (for a review see Roggeveen, Grewal, and Hill, 2016). One factor that has not been looked at is the role of the consumer. By role, we mean whether the consumer was the original complainer or if he/she was an outsider who came across the complaint (i.e., a reader). We hypothesized writers and readers would prefer different response types as they have different needs that must be met post-complaint.
In Studies 1 and 2 we manipulated consumer type (writer of complaint or reader of complaint), complaint type (vindictive or support seeking) and response type (affective, cognitive, or control). Our dependent variable was positive behavioral intentions. For all consumer types and complaints, any type of response (affective or cognitive) was better than not responding to the online complaint at all (the control). For the writers of the complaint, there was no preference for response type (affective or cognitive) after either vindictive or support seeking complaints. For readers of the complaint, we did find a significant difference. If the reader sees a vindictive complaint, they prefer cognitive responses over affective responses. In study 3 we find this preference can be attributed to confidence in the firm and this confidence can be improved by making the cognitive response more concrete (i.e., providing details for how the failure will be addressed). These results suggest, a concrete cognitive response may be best when responding to online complaints as it can improve the behavioral intentions of both the original complainer and readers of the complaint.
Robin B. Saunders  
Chair Communications and Information Management Programs  
Bay Path University  

Abstract  

Title: Social Media Analytics  

Social media analytics is the art and science of extracting valuable hidden insights from vast amounts of semi-structured and unstructured social media data to enable informed and insightful decision-making. It is a science, as it involves systematically identifying, extracting, and analyzing social media data using sophisticated tools and techniques. It is also an art, interpreting and aligning the insights gained with business goals and objectives. In order to get value from analytics, one should master both its art and science. This research explores concepts, tools, tutorials, and case studies that business managers need to extract and analyze the seven layers of social media data, including text, actions, networks, apps, hyperlinks, search engines, and location layers.
Analysis of Gaming YouTuber Influence using Structural Equation Modeling

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INTRODUCTION

Gaming and YouTube

The videogame industry has seen a drastic change in the last few decades both in the technology employed and in its business environments. The graphics and physics engines achieved a realistic visual representation that enables a truly immersive experience. Figure 1
shows such advancement. The rapid development of Internet and the rising concerns for digital piracy and intellectual property rights (Maggiorini & Ripamonti, 2011) have changed the way gamers purchase, own, and enjoy videogames. Whereas videogames used to be either off-line single-player or on-line multiplayer oriented, recent games show a trend of being more online oriented, even for games that do not provide multiplayer environments (Riungu-kalliosaari et al., 2011). Whereas gamers had to visit game stores to purchase a new game in a package, today’s gamers can purchase games online and download them to their computers or consoles (Figure 2). New videogames that are launched, thus, tend not to be considered a ‘finished product’ as they used to be in packaged games, and leave possibilities of fixes, updates, and additional downloadable contents (DLCs) (Lee et al., 2015). This can be seen in various games that were launched in 2016: Tom Clancy’s the Division (Ubisoft Entertainment, 2016b), shortly after launch, announced a plan for the upcoming year’s major DLC updates that will provide additional playable areas and new game mechanics; Hitman (IO Interactive, 2016), launched
with only one story mission; the developer has since been updating the game with additional story missions and user-created sub-missions, and as of the end of season 1 in November 2016, it had 7 story missions, 36 user-created sub-missions, and 2 developer bonus missions.

The most impressive and interesting outcome of the progress toward today’s videogame community, however, is the rise of a new occupation called ‘gaming YouTuber’. These are content creators on YouTube that specialize in videogame contents, and millions around the world spend time watching them playing videogames and commenting (Jerslev, 2016). YouTube has become the primary outlet for video contents in the entire world and an online go-to place for every perceivable interest. After being purchased by Google for $1.65 billion dollars in 2007, YouTube started letting content creators monetize their videos, creating a new form of career that turned some individuals into billionaires. As of July 2016, YouTube has paid out $2 billion to rightsholders who have chosen to monetize claims since 2007 (YouTube, 2016a). The influence of the most popular YouTubers are more powerful than that of mainstream celebrities, among U.S. teenagers (Ault, 2014) and college students (Ahlquist, 2013). PewDiePie, a Swedish YouTuber, gained huge popularity with his “Let’s Play” videos, where he would play videogames and comment on them. PewDiePie is now also the most subscribed and the most viewed YouTuber in the world, making up to more than 500,000 Dollars monthly (Socialblade, 2016). Recognizing the surge of gaming YouTube channels in the platform, in the summer of 2015, YouTube launched YouTube Gaming, a separate platform that focuses on videogame contents (Gaudiosi, 2016).
THEORETICAL BACKGROUND

Gaming YouTubers and the videogame industry

Gaming YouTubers, beyond the entertainment they provide to viewers and subscribers, pose a significant opportunity to the videogame industry to improve their performance. Extant literature in the marketing discipline of business research examine the influence of word-of-mouth (WOM). Meuter et al. (2013) found that independent sources (i.e. Facebook and Yelp.com) are more influential than company-controlled sources, such as customer testimonials on a firm website. Smith et al. (1999) found that high-technology firms are more likely to use word-of-mouth and outside experts as information sources. The ‘influence the influencer’ promotional strategies, i.e. where the firm gives products for free to influential YouTubers to spread the word-of-mouth, are prominent among various firms that actively engage in YouTube activities. Such practice leads to video contents in the formats of: ‘unboxing’, where the YouTuber shares the first impressions taking the product out of the box; ‘preview’, where they share the initial impressions and expectations for the product; and ‘review’, where they share the impressions after using the product.

In the gaming environment, YouTubers take a unique position beyond the conventional word-of-mouth influencers. The mainstream game developers are increasingly including gaming YouTubers, or gamers in general, into their decision-making processes. The aforementioned case of IO Interactive, the developer of Hitman (2016), is an example of such novel practice. Massive, the developing studio of Tom Clancy’s the Division (Ubisoft Entertainment, 2016b), postponed a major additional content DLC update in Fall 2016 to fix the broken balance of the game. They then opened a public test server (PTS) where players are given early access to the
upcoming update, as well as a forum to take feedback from the PTS experience. They also invited a randomly selected group of players to their studio in Malmö, Sweden, to have them play the upcoming version of the game and receive live feedback (Ubisoft Entertainment, 2016a). The developers at Massive Studios also communicate their weekly progress in a discussion video called “State of the Game” (mimicking State of the Union speeches), which is then disseminated by gaming YouTubers.

Social network theory

Social network theory (SNT) examines ties or links among actors, addressing how patterns of social ties produce better economic outcomes, and why inter-organizational networks form, collapse, succeed, or fail (Kim, 2014). Structural embeddedness, a key term in SNT, posits that when actors are embedded within a network, they show preference for transacting with network members; social ties are forged, renewed, and extended through the community rather than through outside members (Granovetter, 1973; Kilduff & Brass, 2010; Uzzi, 1996). While structural embeddedness is typically used to understand buyer-supplier relationship in supply chain management (SCM) research, this paper will use it to examine the novel approach that game developers are taking, by embedding gamers into their supply chains.

In a comparison of Twitter and YouTube networks in information diffusion, Park et al. (2015) find that a Twitter network has a hub-and-spoke structure, thus is ideal for organizing and coordinating information and facilitating exchange of ideas between different groups. On the other hand, a YouTube network has a dense and interconnected structure, suitable for disseminating ideas and reinforcing solidarity among members (Park et al., 2015). Figure 3
shows the difference between the two social media interactions, which suggests that YouTube can be an effective platform on which developers can build a strong, supportive community of gamers.

As a preliminary study of examining how firms can manage their relationships with influential gaming YouTubers to their advantage and enhance performance, this study will utilize the social network theory from the supply chain management discipline and literature on word-of-mouth from the marketing discipline, as well as various research in communications, to analyze what factors make gaming YouTubers influential. This study will primarily examine whether being a full-time gaming YouTuber has a significant advantage over being a part-time YouTuber on influence and take other characteristics of the YouTube channel and videos into account. This study extends the social network theory by applying it to the videogame industry.

Figure 3. Network on Twitter (left) and YouTube (right) (Park et al., 2015).
HYPOTHESES

Holmbom (2015) argues that being a YouTuber can be a very heavy investment of life with an intense lifestyle, and may completely consume one’s time and energy. Thus, the first hypothesis:

H1. Being a full-time YouTuber will have a positive effect on influence.

However, it is hypothesized that gaming YouTuber influence is affected by the level of gravity (attractiveness of the YouTube channel) and communication (how the YouTuber communicates with viewers and developers). Thus, the revised H1, H2, and H3:

H1. Being a full-time YouTuber will enhance: a) gravity and b) communication, and thus have a positive effect on influence.

H2. Attractiveness to YouTube channel will have a positive effect on influence.

H3. Better communication with viewers and developers will have a positive effect on influence.

The items that construct the mediating factors (gravity, communication) and the dependent variable (influence) will be further discussed in the methods section.
METHODS

Data collection

This study will use data available from YouTube and an online YouTube statistics provider. The top 500 most subscribed gaming YouTube channels (Socialblade, 2016) will be the starting point of the data. The number of subscribers of the most and least subscribed channel was 49,163,225 and 1,166,880.

Model

This study will utilize confirmatory factor analysis (CFA) to validate proposed items for related factors (Jackson et al., 2009; Noar, 2003), and then use latent variable modeling (LVM) to test the hypotheses (Muthén, 2002). LVM encompasses path analysis (PA) and confirmatory factor analysis (CFA) (Harlow, 2014). The data will be analyzed with EQS software for structural equation modeling (Bentler, 1989-2015).

The nine item parcels that consist of nineteen items are developed from extant research: catchiness from research on the effect of visual design of web ads on online purchase decision (Shaouf, Lü, & Li, 2016), exposure from research on intersections between popularity metrics and digital composition (Yoganarasimhan, 2012), company involvement from research on levels of involvement with company and intentions to subscribe and recommend (Chun & Lee, 2016), comment response from research on communicative practices on YouTube (Tolson, 2010), videos from research on YouTuber popularity (Holmbom, 2015) and the best video length for different videos on YouTube (Minimatters, 2015), developer relationship from research on levels of involvement with company and intentions to subscribe and recommend (Chun & Lee, 2016), likes/dislikes from research on what motivates user participation and consumption of
YouTube (Khan, 2017) and on intersections between popularity metrics and digital composition (Wuebben, 2016), *additional exposure* from research on social media performance metrics and the impact on brand building (Moro et al., 2016), and *viewer participation* from research on what motivates user participation and consumption on YouTube (Khan, 2017). The detail on items and the relationship with item parcels are shown in Table 1. Each item parcel is the mean of its consisting items.
<table>
<thead>
<tr>
<th>Table 1. Items, item parcels, and supporting literature.</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Gravity</strong></td>
</tr>
<tr>
<td>Gravity 1</td>
</tr>
<tr>
<td>Gravity 2</td>
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<tr>
<td>Gravity 3</td>
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<td>Gravity 4</td>
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<td>Gravity 5</td>
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<tr>
<td>Gravity 6</td>
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<tr>
<td>Gravity 7</td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th><strong>Communication</strong></th>
<th><strong>Video</strong></th>
<th><strong>Influence</strong></th>
<th><strong>Like/Dislike</strong></th>
<th><strong>Engagement</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Communication 1</td>
<td>Developer relationship</td>
<td>11</td>
<td>11</td>
<td>10</td>
</tr>
<tr>
<td>Communication 2</td>
<td>Number of views</td>
<td>10</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>Communication 3</td>
<td>Number of comments weekly</td>
<td>11</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>Communication 4</td>
<td>Number of subscribers</td>
<td>11</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>Communication 5</td>
<td>Directly speaks with developer</td>
<td>12</td>
<td>12</td>
<td>12</td>
</tr>
<tr>
<td>Communication 6</td>
<td>Included in developers decision making</td>
<td>13</td>
<td>13</td>
<td>13</td>
</tr>
</tbody>
</table>

**Northeast Decision Sciences Institute 2017 Annual Conference**
The CFA model is shown in Figure 4. The full model for LVM is shown in Figure 5. For the LVM analysis, three nested models will be analyzed: mediational, direct effects, and full effects LVM. The mediational model will examine the mediated path from X1 Fulltime through F1 Gravity and F2 Communication to F3 Influence, fixing the direct path from X1 to F3 at 0. The direct effects LVM will examine the direct path from X1 to F3, fixing all other paths at 0. Finally, the full effects LVM will examine all paths, direct and mediational.

![Figure 4. CFA model.](image)

![Figure 5. Full model for LVM.](image)
EXPECTED RESULTS

It is expected that the CFA will show a $\chi^2$ value in the reasonable range (2-3 times df), thus $48 \leq X^2 \leq 72$, $p < .001$ is expected. Also the comparative fit index (CFI) is expected to be high, close to 1. The root mean square error of approximation (RMSEA) is expected to be low, close to 0. For the LVM nested model analysis, it is expected that the full effects model will show the best fit, with $40 \leq X^2 \leq 60$, $p < .001$, CFI close to 1, and RMSEA close to 0. Overall, it is expected for all hypotheses, H1a, H1b, H2, and H3, to be supported.

LIMITATIONS AND FUTURE DIRECTIONS

This paper uses a readily available online data from a YouTube statistics provider, which may be imperfect or unreliable in the selection of relevant YouTube channels. Also, the list obtained consists of the top 500 channels in gaming. When there are currently about 6.53 million gaming channels on YouTube (YouTube, 2016b), it only captures the top tier of the community.

Currently, the three major gaming platforms are PC, Playstation4, and Xbox1. This paper does not account for the platform variance, and is primarily based on a PC gamer perspective. Also, the implications of this research may be limited to large-sized developers and AAA (major or flagship franchise) games.

Mods (modifications) is one of the most important themes in the current gaming industry regarding the involvement of players in the production of games. This paper, however, does not take mods into account because the discussions here are more concerned with the online interaction and influence on YouTube than the co-creation of actual contents (Davidovici-nora,
Future study on the developer-embedded gamers will benefit taking this important theme into consideration.

The long-term goal of the study is to examine the benefits and pitfalls of embedding gamers within developer supply chain, asking how and to what extent developers can benefit from such practice. Several case studies on the industry examples, as mentioned earlier in this paper, will help formulate empirical models and theory-building.
REFERENCES


Site selection of air and spaceport for space tourism

Site Selection of Air and Spaceport for Space Tourism Using Multi-Criteria Approach

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Abstract
Hawaii has been identified as a desirable space launch location since the early days of spaceflight. The purpose of the site selection study was to evaluate and identify a site within the State of Hawaii to support spaceport operations for horizontally operated reusable launch vehicles (RLV) that utilize conventional airport runways for launch and recovery operations. The site selection study began by identifying sites with potential for launch and recovery operations. Excluding facilities dedicated exclusively for military and seaplane use, 27 airports were investigated in the state. The study recommends the selected airport of Kona develop a design plan for cost effective operations and maintenance as well as environmental impact mitigation plans.

Keywords: Space tourism, spaceflight, site selection, space port
Site selection of air and spaceport for space tourism

1. Introduction and background

Hawaii has been identified as a desirable space launch location since the early days of spaceflight. It was even considered by NASA in the 1960s during the Moon Race era but not selected due to high cost of development. The fundamental physics of space launch, especially for large geostationary Earth orbit (GEO) satellites, has continued to drive successive waves of interest in an orbital launch facility in Hawaii.

As the commercial space industry matures, the State of Hawaii is uniquely positioned to be an active participant in several key areas of commercial space. Space tourism is one of the primary driving forces of the commercial space industry, and advances in suborbital space planes will allow the development of spaceports that utilize existing airports for launch operations.

The purpose of the site selection study was to evaluate and identify a site within the State of Hawaii to support spaceport operations for horizontally operated reusable launch vehicles (RLV) that utilize conventional airport runways for launch and recovery operations. The site selection study began by identifying sites with potential for launch and recovery operations. Several evaluation criteria were used to narrow the sites down to five candidate locations, which were then assessed in greater detail to determine the location that was most compatible with commercial spaceport operations. Based on the results of the analysis, recommendations for spaceport development were provided.

The primary tasks identified as required for an effective site selection study were to (1) Identify sites with good potential to be a launch/recovery site and (2) establish a method for quantifying the potential of each site by considering such factors. The factors include existing facilities, explosive siting, ease of access, expense of development, risk to uninvolved third parties, impact on commercial and military air traffic, breadth of potential operations (i.e., reusable suborbital, expendable suborbital, expendable or partially expendable orbital, re-entry operations; for orbital operations, viable inclinations/missions).

This study used the following assumptions. Only horizontally launched reusable launch vehicles were considered at a potential site; vertical launch vehicles were not considered in this study. Both suborbital and orbital missions would be possible. A potential site was limited to existing airports to reduce overall capital investment.

The structure of this paper is as follows: Section 2 introduces spaceport licensing and regulations in general followed by Section 3, which explains launch vehicles including options and detailed horizontal reusable launch vehicles (RLV). The horizontal RLV presents three generic concepts of Concepts X, Y, and Z. Section 4 demonstrates multi-criteria decision making process for selecting the best site in Hawaii integrating pass-fail test, and criteria weighting method. Results are interpreted in Section 5. Section 6 concludes the study.

2. Spaceport Licensing and Regulations

Before an airport is able to conduct space launch activities and operate as a commercial spaceport, the airport must be licensed by the Federal Aviation Administration Office of Commercial Space Transportation (FAA/AST). The FAA issues licenses for commercial launch sites, as well as licenses for specific vehicle operators at those launch sites, when it determines that an applicant’s proposal to operate a launch or reentry site would not jeopardize public health, safety, the safety of property, United States national security, foreign policy interests, and or international obligations of the United States. The regulations that govern spaceport licensing can be found in Chapter III of Title 14 of the Code of Federal Regulations (CFR) Part 420 – License to Operate a...
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Launch Site, also known as 14 CFR Part 420. The license application procedures are found in 14 CFR Part 413. (Government Printing Office)

A license to operate a launch site authorizes the licensee to offer that site to an operator of a launch vehicle of the type and weight class identified in the license application. A launch vehicle operator must independently obtain a vehicle-specific license and demonstrate that they can safely operate from the licensed spaceport. The result is that it is possible for a spaceport to be licensed but not have any licensed operators utilizing the licensed facilities.

While the launch vehicles considered in this study operate from airports like conventional aircraft, they do require unique facilities and have siting requirements typically not found for other transportation equipment.

3. Launch Vehicles

3.1. Launch Vehicle Options
Historically, spacecraft have been launched in a vertical configuration from a fixed launch pad located at national ranges, such as Cape Canaveral in Florida or Vandenberg Air Force Base in California. These ranges have supported both suborbital launches and orbital launches. Suborbital vehicles have typically consisted of sounding rockets and modified intercontinental ballistic missiles. Orbital launch vehicles are significantly larger and carry much greater quantities of propellants than suborbital launch vehicles.

Over the past decade there has been a shift in the industry and a large number of small companies have developed a wide range of different types of launch vehicles that deviate from the traditional approach to launching spacecraft. Some of these new launch vehicles resemble airplanes and are designed to take off and land on runways, while others take off and land in a vertical configuration. (Gulliver, Ibold, Sandifer, & Fingers, 2012) These horizontal reusable launch vehicles are those compatible with aviation operations and infrastructure, and were the focus of this study.

3.2. Horizontal Reusable Launch Vehicles
A horizontal RLV is a launch vehicle that utilizes runways to take off and land like an airplane. These RLVs resemble airplanes and most operate on jet fuel for portions of their flight. There are currently three generic concepts for RLVs that are considered in this study, referred to as Concept X, Concept Y, and Concept Z.

Concept X: The Concept X launch vehicle is a dual-propulsion RLV, similar to an airplane, that takes off from a runway using jet power and flies to a safe location and high altitude before igniting its rocket engines to complete its launch path. Upon completion of its mission, the Concept X launch vehicle will return for a horizontal landing by either restarting its jet engines or by gliding unpowered. Current Concept X launch vehicle concepts would be about the size of a medium business jet and capable of providing suborbital flights for both passengers and cargo. An example of a Concept X launch vehicle is the Rocketplane XP being developed by Rocketplane Global, Inc. Although Rocketplane Global declared bankruptcy in mid-2010, it is still working on finding investment capital to complete its design. Additionally, Rocket Crafters Inc. is in the process of developing a Concept X RLV named Sidereus.

Concept Y: The Concept Y launch vehicle is an all-in-one RLV that ignites its rocket engines while on the ground and takes off horizontally from a runway. This RLV is under rocket power until engine cutoff during ascent of its suborbital trajectory. Upon completion of its suborbital flight path it then returns gliding unpowered for a horizontal landing. Current generation
Concept Y launch vehicles would be capable of providing suborbital flights for both passengers and cargo. An example of a Concept Y launch vehicle is the Lynx being developed by XCOR Aerospace.

Concept Z: The Concept Z launch vehicle is a two-part launch vehicle consisting of a reusable carrier aircraft and a reusable or an expendable launch vehicle. The carrier aircraft is powered by jet engines and designed/modified to carry the launch vehicle to a high altitude, where the two components detach and the rocket engine of the launch vehicle is ignited. The carrier aircraft flies back to the Spaceport and lands normally. The launch vehicle, which can be either suborbital or orbital, completes its mission path and either returns for a horizontal landing or is expended. Two examples of Concept Z launch vehicles include the Orbital Sciences Pegasus and its carrier aircraft, a modified Lockheed L-1011 transport aircraft, and Scaled Composites’ SpaceShipTwo and its carrier aircraft the WhiteKnightTwo. Current generation Concept Z launch vehicles are capable of providing suborbital flights for both passengers and cargo, and orbital launch capability for satellite payloads.

4. Site selection study
The process of selecting a Hawaii airport to be considered for licensure as a spaceport began with identifying all potential public-use airports in Hawaii in Step 1 and then down selecting to a single airport that is most compatible with spaceport operations in Step 2. Favorable airport characteristics included, but were not limited to, long runway(s), available land for development, minimal population density nearby, compatible air route structure, compatibility with aviation operations, and proximity to tourism amenities. The following sections define the Hawaii airport system, the pass/fail analysis to quickly rule out incompatible airports, and a detailed analysis of the remaining airports to determine which Hawaii airport is the best candidate for spaceport licensure.

4.1. Hawaii Airport System
The State of Hawaii is the home to a wide variety of aviation activities ranging from recreational, sightseeing, agricultural and military flights, to business and commercial passenger activities. The airports that serve the State not only support these various activities, but also provide a crucial link in connecting the “Crossroads of the Pacific” to the mainland and the world. Excluding facilities dedicated exclusively for military and seaplane use, there are 27 airports in the State of Hawaii, and their locations are shown in Figure 1. The Airports Division of the Hawaii Department of Transportation (HDOT) currently operates and maintains 15 of these airports as the unified state airport system. The remaining 12 airports represent privately owned and registered facilities not typically available for public use. (Hawaii Department of Transportation, 2014; Bureau of Transportation Statistics, 2015)
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Figure 1. Private and public airports in Hawaii (map by the authors).

4.2. Multi-criteria Method

Each alternative location would be tested for pass and fail. If the location passed the test, five attributes and line items for each factor (i.e. category) will be used for double weighted average method (see Figure 2). Five categories, A ~ E, are considered for the locations passed with A. Infrastructure/Existing facility, B. Concept (X/Z), C. Concept (Y), D. Business Case, and E. Environmental. Each category includes line items (i.e. attributes): Category A include 7 line items, Category B with 4 line items, Category C with 4 line items, Category D with 6 line items, and Category E with 3 line items.

Figure 2. Framework of the multi-criteria decision making for a spaceport.
For double-weighting method (Equation 1), line items were weighted ($w_i$). The average weighted line items for each category were aggregated. The aggregated line item scores for each category were weighted by the category’s weight ($w_c$). The locations are examined by two pass/fail tests ($y_a$). The location which is not passed has the value ($y_a$) of 0, so it will automatically omitted form the alternatives.

$$P_l = y_a \cdot \sum_{c=1}^{N} \left\{ \left( \sum_{i=1}^{F_c} x_{ci} \cdot w_{ci} \right) w_c \right\}, \forall l = \{1, 2, ..., K\}$$

Where $P_l$ = weighted priority score on location $l$

- $x_{ci}$ = normalized score on line item $i$ of category $c$
- $w_{ci}$ = weight on line item $i$ of category $c$
- $w_c$ = weight on category $c$
- $F_c$ = a set of line items for each category $c$
- $N$ = a set of categories, $\{1, 2, ..., 5\}$
- $y_a = 1$ if pass, 0 if fail in the pass-fail test for each test $a$

### 4.2.1. Step 1 - Pass/Fail Analysis

The first step in selecting a site is to use specific pass/fail criteria to narrow down the potential sites to those that are most compatible with commercial spaceport operations.

Two criteria, based on the runway length requirements of Concept X, Y, and Z RLVs, were used to complete the pass/fail analysis. Concept X RLVs require a runway between 6,900 and 10,000 feet long; Concept Y RLVs require a runway between 6,500 and 7,000 feet long; Concept Z RLVs require a runway between 10,000 and 12,000 feet long. For this analysis, criterion one must be passed to move on to criterion two and an airport must receive a “Pass” for both criteria to proceed to Step 2, Airport Evaluation. The selected criteria include the following:

1. Does the Airport have a runway longer than 6,000 feet ($y_{a=1}$)?
2. Is a runway extension to 10,000 feet possible if not already that length ($y_{a=2}$)?

The Hawaiian public-use airports were subject to the first pass/fail runway length evaluation. If any runway at an airport is longer than 6,000 feet, then a “Pass” rating was issued for that runway ($y_1=1$). A “Fail” rating was assigned if the airport did not have any runway that met this requirement ($y_1=0$).

Only the airports that passed the first criterion were evaluated with the runway extension criterion. This second criterion evaluates the land on each end of the passing runway to determine if an extension to a minimum of 10,000 feet is possible while still retaining sufficient Runway Safety Area. Engineering judgment was used based on the availability of land and the type of terrain. If the land on either end of a runway was judged to be fit for an extension, that runway received a “Pass” rating ($y_2=1$). If a runway extension was considered not feasible, a “Fail” grade was applied ($y_2=0$). Existing runways that were longer than 10,000 feet automatically received a “Pass” for both criteria.
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Of the 27 Hawaii airports considered for the pass/fail analysis, seven airports passed the first criterion of the pass/fail analysis, and of those, five passed the second pass/fail criterion. The five airports that passed both criteria of Step 1 were moved forward to Step 2 – Site Evaluation. Table 1 provides the outcome of the pass/fail analysis for each of the 27 airports. If an airport had at least one runway that passed both criteria, the airport passed the pass/fail analysis. Five airports passed Step 1 including Honolulu International Airport, Kona International Airport, Hilo International Airport, Kalaeloa, and Kahului Airport (see Table 1).

4.2.2. Step 2 – Airport Evaluation

Evaluation Criteria: Following the Step 1 pass/fail analysis that filtered out incompatible airports, Step 2 scored the five remaining compatible airports according to characteristics deemed important in determining their long-term suitability for spaceport operations. The evaluation criteria were developed and grouped based on seven factors of which include:

- Existing facilities
- Explosive siting
- Ease of access
- Expense of development
- Risks to uninvolved third parties
- Impact on commercial or military air traffic
- Breadth of potential operations

Five evaluation criteria categories were developed that include the seven factors above.

A. Infrastructure and existing facilities
B. Airspace (Concept X and Z)
C. Airspace (Concept Y)
D. Business case
E. Environmental

Each of the five categories was assigned a weighting factor to represent its relative importance in the requirements associated with operating as a spaceport. The weight is expressed as a category percentage based on engineering judgment and past experience with spaceport studies. The weighting factors were subjectively assigned by a team of three professionals: a spaceport and airport planner from RHS Inc., a launch facilities engineer, and a National Environmental Policy Act (NEPA) specialist. Each element was considered from a multidisciplinary point of view, with the environmental aspects slightly “overvalued” due to the community concerns that are prevalent in the Hawaiian Islands. (See Figure 2).

Airport Evaluation Method: For each of the factors within the five categories, a team of experienced spaceport planners evaluated each airport and assigned it a numerical rating of 1 to 5. Unless otherwise noted, a rating of 5 indicates the concept was judged to have the highest or “best” potential for meeting the factor’s objective (e.g. least risk, lowest cost, least interference, best compatibility, etc.) and a rating of 1 indicates the airport was judged to have the lowest or “worst” potential for meeting the objective being considered.

Category A, Infrastructure / Existing Facilities, was 25% of the airport score for the influence each category A line item had on the airport score (Figure 3). Category B, Airspace (Concept X / Z), was 17.5% of the airport score for the influence each category B line item had on
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the airport score. Category C, Airspace (Concept Y) was 17.5% of the total airport score for the influence each category C line item had on the airport score. Category D, Business Case, influenced the total airport score by 20% for the influence each category D line item had on the airport score. Category E, Environmental, was weighted at 20% of the airport score. Each element was considered from a multidisciplinary point of view, with the environmental aspects slightly “overvalued” due to the community concerns that are prevalent in the Hawaiian Islands.

Table 1. Pass/Fail Analysis Airport Results Summary

<table>
<thead>
<tr>
<th>Region</th>
<th>Airports</th>
<th>FAA Identifier</th>
<th>Runway</th>
<th>&gt;=6000 ft</th>
<th>&gt;=10000 ft</th>
<th>Both Criteria</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hawaii</td>
<td>Hilo International</td>
<td>ITO</td>
<td>Pass</td>
<td>Pass</td>
<td>Pass</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Honokaa Airstrip</td>
<td>H105</td>
<td>Fail</td>
<td>-</td>
<td>Fail</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kaalaiki Airstrip</td>
<td>H125</td>
<td>Fail</td>
<td>-</td>
<td>Fail</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kona International</td>
<td>KOA</td>
<td>Pass</td>
<td>Pass</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Mountain view Airstrip</td>
<td>HI23</td>
<td>Fail</td>
<td>-</td>
<td>Fail</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Pahala Airstrip</td>
<td>H128</td>
<td>Fail</td>
<td>-</td>
<td>Fail</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Upolu</td>
<td>UPP</td>
<td>Fail</td>
<td>-</td>
<td>Fail</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Upper Paauau</td>
<td>HI29</td>
<td>Fail</td>
<td>-</td>
<td>Fail</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Upper Pauulo Airstrip</td>
<td>HI27</td>
<td>Fail</td>
<td>-</td>
<td>Fail</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Waimea-Kohala</td>
<td>MUE</td>
<td>Fail</td>
<td>-</td>
<td>Fail</td>
<td></td>
</tr>
<tr>
<td>Kauai</td>
<td>Haiku Airstrip</td>
<td>HI33</td>
<td>Fail</td>
<td>-</td>
<td>Fail</td>
<td></td>
</tr>
<tr>
<td></td>
<td>HI 23 Airstrip</td>
<td>HI03</td>
<td>Fail</td>
<td>-</td>
<td>Fail</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lihue</td>
<td>LIH</td>
<td>Pass</td>
<td>Fail</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Port Allen</td>
<td>PAK</td>
<td>Fail</td>
<td>-</td>
<td>Fail</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Princeville</td>
<td>HI01</td>
<td>Fail</td>
<td>-</td>
<td>Fail</td>
<td></td>
</tr>
<tr>
<td>Maui</td>
<td>Brandt Field</td>
<td>18HI</td>
<td>Fail</td>
<td>-</td>
<td>Fail</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Hana</td>
<td>HNM</td>
<td>Fail</td>
<td>-</td>
<td>Fail</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kahului</td>
<td>OGG</td>
<td>Pass</td>
<td>Pass</td>
<td>Pass</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kapalua</td>
<td>JHM</td>
<td>Fail</td>
<td>-</td>
<td>Fail</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Lanai</td>
<td>LNY</td>
<td>Fail</td>
<td>-</td>
<td>Fail</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Panda</td>
<td>HI49</td>
<td>Fail</td>
<td>-</td>
<td>Fail</td>
<td></td>
</tr>
<tr>
<td>Molokai</td>
<td>Kalaupapa</td>
<td>LUP</td>
<td>Fail</td>
<td>-</td>
<td>Fail</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Molokai</td>
<td>MKK</td>
<td>Fail</td>
<td>-</td>
<td>Fail</td>
<td></td>
</tr>
<tr>
<td>Oahu</td>
<td>Dillingham Airfield</td>
<td>HDH</td>
<td>Pass</td>
<td>Fail</td>
<td>Fail</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Honolulu International</td>
<td>HNL</td>
<td>Pass</td>
<td>Pass</td>
<td>Pass</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Kalaeloa (Barbers Point)</td>
<td>JRF</td>
<td>Pass</td>
<td>Pass</td>
<td>Pass</td>
<td></td>
</tr>
</tbody>
</table>

Within each category, a variable number of component factors was used to examine specific attributes of each airport. Each of these was also assigned a weighted value relative to other factors within the category. The sum of the influence of all factors within a category is equivalent to the total category weight. Each line item therefore has a weighted influence on the overall concept evaluation.
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**Figure 3.** Evaluation category weights.

**Category Line Item Score and Weighting:** Each line item of an evaluation category was assigned a score from 1 to 10, with 1 indicating that the characteristic is the least critical, and 10 most critical. Each line item within a category is scored independently, to ensure that the rating of any individual item does not affect the rating of any other item. The score of each line item was then combined with the score of its category to determine the category influence that the line item had on the final airport score. Figure 4 illustrates the complete comparison of the line items and their influence on the total airport score, depicted in decreasing order of weighting.

Each line item’s weight of an attributes was fraction of total score of the attribute as shown below

\[
w_{ci} = \frac{S_{ci}}{\sum_{i=1}^{N} S_{ci}}, \forall a = \{1,2,...,N\}
\]

where \(w_{ci}\) is a new weight of line item \(i\) of the category \(c\); \(S_{ci}\) is the score of a line item \(i\) of the category \(c\).

5. **Results**

Following the analysis of the initial 27 airports in the pass/fail analysis, the five airports receiving a passing score were further evaluated using the 5 criteria categories and the 24 category specific line items described in Section 4.

Kona (KOA) received the highest composite score (4.196). Honolulu (HNL), Hilo (ITO) and Kalaeloa (JRF) scored about 3.455, while Kahului (OGG) scored the lowest at 2.993. Based on the results of the detailed evaluation, Kona International Airport has been selected for further development. Table 2 provides the detailed results of the evaluation of each airport.

KOA is the most favorable with respect to infrastructure / Existing facility by the average of 4.095, while KOA earned the average score of 1.095. However, JRF is the airport which provides existing facility for a potential space port. Even if KOA is the airport received the highest overall score, accessibility should be improved.
For Concept (X/Z), all the line items of KOA received five points, followed by ITO with the score of 4.720. The compatible air route structure of IRO is relatively less scored than KOA.

HNL earned the highest score of 4.158 for Business Case because HNL provides relatively better proximity to tourist amenities than other airports. All airports illustrate opportunities in aerospace, education, and research. However, all alternatives should find ways to cost effective ways to maintain and operate the facilities.

All airports need to address environmental impacts appropriately. HNL illustrate the highest environmental average score by 4.0, while KOA, which is most favorable facility overall, earned the average score of 3.692. Especially, potential indirect environmental impact should be address along with the local noise and direct environmental impact.
Table 2. Airport evaluation results

<table>
<thead>
<tr>
<th></th>
<th>HNL</th>
<th>KOA</th>
<th>ITO</th>
<th>JRF</th>
<th>OGG</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Honolulu</td>
<td>Kona</td>
<td>Hilo</td>
<td>Kalealoa</td>
<td>Kahului</td>
</tr>
<tr>
<td>A: Infrastructure / Existing Facility (25%)</td>
<td>3.500</td>
<td>4.095</td>
<td>3.000</td>
<td>3.381</td>
<td>2.333</td>
</tr>
<tr>
<td>A1. Spaceport operations compatible with airport</td>
<td>3</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>4</td>
</tr>
<tr>
<td>A2. Safety area compatibility</td>
<td>4</td>
<td>5</td>
<td>2</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>A3. Existing available facilities</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>3</td>
<td>1</td>
</tr>
<tr>
<td>A4. Availability of land for development</td>
<td>2</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>1</td>
</tr>
<tr>
<td>A5. Existing runway length / width</td>
<td>5</td>
<td>4</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>A6. Future runway length potential</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>A7. Ease of access</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>B: Concept (X/Z) (17%)</td>
<td>3.560</td>
<td>5.000</td>
<td>4.720</td>
<td>3.760</td>
<td>3.760</td>
</tr>
<tr>
<td>B1. Minimal population density</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>B2. Compatible air route structure</td>
<td>2</td>
<td>5</td>
<td>4</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>B3. Impact on commercial or military air traffic</td>
<td>2</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>B4. Compatible with orbital azimuths</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>C: Concept (Y) (18%)</td>
<td>1.800</td>
<td>4.360</td>
<td>3.680</td>
<td>3.040</td>
<td>2.640</td>
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<tr>
<td>C1. Minimal population density</td>
<td>3</td>
<td>4</td>
<td>3</td>
<td>5</td>
<td>4</td>
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<tr>
<td>C2. Compatible air route structure</td>
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<td>5</td>
<td>4</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>C3. Impact on commercial or military air traffic</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>C4. Compatible with orbital azimuths</td>
<td>1</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>D: Business Case (20%)</td>
<td>4.158</td>
<td>3.947</td>
<td>3.053</td>
<td>3.211</td>
<td>3.211</td>
</tr>
<tr>
<td>D1. Proximity to tourist amenities</td>
<td>5</td>
<td>4</td>
<td>2</td>
<td>3</td>
<td>4</td>
</tr>
<tr>
<td>D2. Breadth of potential operations</td>
<td>5</td>
<td>5</td>
<td>3</td>
<td>3</td>
<td>2</td>
</tr>
<tr>
<td>D3. Aerospace/education/research opportunities</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>D4. Capital investment to support a single operator</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>D5. Capital Investment to support multiple operators</td>
<td>4</td>
<td>4</td>
<td>3</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>D6. Operations and maintenance costs</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>E: Environmental (20%)</td>
<td>4.000</td>
<td>3.692</td>
<td>2.846</td>
<td>3.615</td>
<td>3.000</td>
</tr>
<tr>
<td>E1. Local noise sensitivity/compatibility</td>
<td>4</td>
<td>4</td>
<td>1</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>E2. Potential for direct environmental impact</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>4</td>
<td>2</td>
</tr>
<tr>
<td>E3. Potential for indirect environmental impact</td>
<td>4</td>
<td>3</td>
<td>4</td>
<td>4</td>
<td>4</td>
</tr>
<tr>
<td>Double Weighted Average</td>
<td>3.455</td>
<td>4.196</td>
<td>3.434</td>
<td>3.426</td>
<td>2.993</td>
</tr>
<tr>
<td>RANK</td>
<td>2</td>
<td>1</td>
<td>3</td>
<td>4</td>
<td>5</td>
</tr>
</tbody>
</table>

Note: Rank 1 - Best, 5 – Worst.

Of five airports passed the pass/fail test, KOA (Kona Airport) received the highest score by 4.196 out of 5.0. However, the airport received low score on the line item of “existing available facilities.” The alternative airport should invest in the existing facility or a new facility. That is linked to the relatively lower line item scores on “capital investment to support a single operator” and “operations and maintenance costs.” The authors recommend the selected airport develop a design plan for cost effective operations and maintenance. In addition, the communities surrounding the alternative facilities concern the potential environmental impacts of noise and
pollution. Hence, the facility should address adequate environmental improvement plans for sustainable business.

The study can be improved by developing a survey instrument from the public and bigger panel to address a variety of stakeholders. The study is based on a group of three experts, resulting in limited analysis of variability among the group.

Acknowledgement

The authors acknowledge the assistance and input of the members of the RS&H commercial spaceport licensing team who participated in this effort, as well as the Hawaii Department of Transportation’s Airports Division and the Hawaii Office of Aerospace Development.

References


A Condensed Statistics Review in a MBA Course
– A Pilot Work

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ABSTRACT
Statistics is a challenging subject for business students. Although the graduate students in our MBA program have taken at least one statistics course during their undergraduate studies, most of them are not capable to use statistics as a tool in their graduate courses as well as in their business practices. This article presents a pilot work of reviewing statistics in a condensed a two-hour lecture, which focuses on the essential ideas of statistical inference, uses Excel to do key calculations, and skips mathematical details unnecessary for business users. This review does not use any textbook and has already been taught in three classes of a MBA course, Managerial Decision Analysis. The results of the outcome assessment of this pilot work have showed that students are able to do statistical inference, hypothesis testing, and determining the minimum sample size in business applications.

If you can’t explain it simply, you don’t understand it well enough.
Albert Einstein

I. Introduction

Statistics usually is a challenging course for business students. In our MBA Program, even students have taken a statistics course at the undergraduate level, most of them do not have a clear concept on what statistics is about and are not capable to use statistics to deal with problems in business.

Managerial Decision Analysis is a required course for MBA students, which covers quantitative models for decision making, including game theory, decision theory, linear programming, waiting line models, etc. Since statistics is important for MBA students in their further studies and business practices but many students are weak in statistics, we decided to have an intensive review on statistics in this course. As a pilot work, we take two class hours to review statistics
which covers confidence interval, statistical inference, hypothesis testing, and calculating the 
adequate sample size.

For this review with only two hours, we need to condense the contents and focus on the most 
important and practical components. Throughout the review, we emphasize the essential of 
statistics, - “statistics is using a sample to tell what the population is like”. We use Excel to do 
key calculations so as to bypass introducing formulas. We skip the mathematical details 
unnecessary for a user of statistics in business. There is no available textbook fitting this 
intensive review. As a substitute of a textbook, we developed slides and put them online as the 
guideline of the lecture. The feedback from students has showed that those slides are effective 
and sufficient for student’s study.

This intensive review has been carried out in three classes of Managerial Decision Analysis in 
the past two years. The assessments of the outcomes have showed that students have caught the 
essential ideas of statistics and are able to use statistics in business analysis and decision making 
after this review.

II. How this Intensive Review Went On

The MBA students have taken statistics at least once in their undergraduate studies. As the start 
of the intensive statistics review, I quizzed about students’ understanding on statistics, 
conceptually, with the three questions.

Question 1: Tell what statistics is by using one short sentence (which differentiates statistics 
from any other subjects).

Question 2: Tell what probability theory is about by using one short sentence.

Question 3: What is the use of probability theory in statistics?

Albert Einstein once said, “If you can’t explain it simply, you don’t understand it well enough.” 
The quiz results were disappointing. In the three sections of the course I taught in the last two 
years, no one gave the correct answer on Question 1 and 3, even no answer was close to the 
correct one. For Question 2, about only 20% students’ answers were close to correctness.

Before providing students with the answers to the three questions, I asked two more questions:

Question 4: If you want to know how many males and females in this classroom now, is statistics 
needed (or do you need to use the knowledge of statistics)?
   - Most students answered correctly: No. What we need is just counting.

Question 5: If you want to know how many people smoke in United States, is statistics needed 
(or do you need to use the knowledge of statistics)?
   - Most students answered correctly again: Yes, we need to use statistics. We need to use 
a “sample” (which is a key word in statistics!).

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Then we discussed the answers to the Question 1, 2, and 3 as the introduction of statistics concepts.

*Answer to question 1*: Statistics is a study of investigating a population by using a sample from it.

*Answer to question 2*: Probability theory is a study of chances.

*Answer to question 3*: When we use a sample to tell what the population is like, errors are inevitable. Probability theory is used to tell the chances of the errors.

After the introduction, I used two class hours and 17 slides to cover statistics topics: confidence intervals on population means and population proportions, statistical inference, hypothesis testing, and minimum sample size determination. No textbook was used. In the lecture, calculations with Excel were demonstrated. Examples of slides are as follows:

<table>
<thead>
<tr>
<th>Slide 5. <strong>Fundamental Procedure of Statistics to tell a character of a population, such as mean, proportion, and trend:</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Step 1</em>. Randomly select a sample of the population and find out the character in the sample;</td>
</tr>
<tr>
<td><em>Step 2</em>. Estimate a likely range of the character in the population based on the sample result by using probability theory.</td>
</tr>
</tbody>
</table>

Step 1 does not have much to teach. The method to do it is just “counting”. The statistics details and difficulties are in Step 2.

The other slides show, by using examples, how Step 2 works for population means and population proportions. We use the confidence interval for multiple purposes such as statistical inference, hypothesis testing, and determining sample size. Examples of those slides are as below, which show the details of calculating confidence interval and doing statistical inference.

<table>
<thead>
<tr>
<th>Slides 6 – 11. <strong>Investigate Population Mean</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Example 1</strong>: We want to know the average weight of boys between 5 and 7 in south Jersey.</td>
</tr>
<tr>
<td><strong>Step 1</strong>.</td>
</tr>
<tr>
<td>A random sample of 100 boys is picked from the population, and the average weight of those 100 boys is 62.7 lbs with standard deviation σ=7.48.</td>
</tr>
<tr>
<td><strong>Step 2</strong>.</td>
</tr>
<tr>
<td>The population mean should be somewhere around 62.7 lbs.</td>
</tr>
</tbody>
</table>
E is found out by using an Excel function:

\[ =\text{CONFIDENCE.T}(\alpha,\sigma,n) \]

where \( \alpha \) is allowable error rate, \( \sigma \) is the standard deviation of the sample, \( n \) is the sample size.

In this example, Step 1 is already done. Sample mean is 62.7 lbs with \( \sigma = 7.48 \).

For Step 2. find value of E with, for example \( \alpha = 0.05 \):

\[ E = \text{CONFIDENCE.T}(\alpha,\sigma,n) = \text{CONFIDENCE.T}(0.05,7.48,100) = 1.4842 \]

Range for population mean: (62.7-1.4842, 62.7+1.4842), i.e., (61.2158 lbs, 64.1842 lbs).

Interpretations of the range (61.2158 lbs, 64.1842 lbs).

- It is the 95% confidence interval that contains the population mean;
- The population mean is in this range with probability 0.95;
- The chance that population mean is not in the range is 5%.

Can we say that the average weight of boys between 5 and 7 is over 61 lbs?

Yes. Since 61 is not within the range (61.2158 lbs, 64.1842 lbs), which is the 95% confidence interval for the population mean, we can say with 95% of confidence that the population mean of average weight of the boys is over 61 lbs.

What if we set allowed error rate \( \alpha = 0.01 \)?

Then, the confidence level would be 99%.

E for 99% confidence interval is:

\[ E = \text{CONFIDENCE.T}(0.01,7.28,100) = 1.9646. \]

99% confidence interval is:

(62.7-1.9646, 62.7+1.9646) = (60.7354, 64.6646).

Can we say that the average weight of the boys is over 61 lbs?

No, since 61 is within the confidence interval.

The last slide is a summary of the review:

**Slide 17. Summary:**

In general, a statistical approach has two steps as seen in the previous examples.
Step 1 is processing the sample data to have its characters such as mean, proportion, and/or SD.
Step 2 is to estimate the accuracy of extending the sample characters to the population.

Throughout the lectures, I kept reminding students of what we were doing with statistics: - Using a sample to tell what the population was like.
III. The Outcome Assessment

I could tell from the students’ reactions and feedbacks in class that they understood and caught the essential idea of statistics and technical details as we covered. After the two-hour lecture, they did the homework which included multiple choice questions for enhancing their understanding of concepts and problem-solving. The effectiveness of this intensive statistics review was assessed by a test, as below.

Test Problems:

1. (20 pts) The average time required to assemble a unit in an assembly process has been 10 minutes. The most recent periodic sample of 22 randomly selected units reveals the following assembly times (in minutes):
   10.8, 10.4, 10.6, 9.8, 9.7, 9.9, 10.4, 9.8, 9.6, 10.7, 10.3, 9.6, 9.9, 11.2, 10.6, 9.8, 10.9, 10.4, 10.5, 9.7, 9.9, 10.8.
   Does the sample significantly suggest that the current average assembly time deviates from the required 10.00 minutes (assuming 95% of confidence level)? If yes, what is the chance of error of the statistical suggestion? (Show your arguments, calculation steps, and conclusions, as well as Excel formulas (functions) and their parameters you use.)

2. (20 pts) The advertising director for a fast-food chain would like to estimate the proportion of high school students who are familiar with a particular commercial broadcast on television in the last month. A random sample of 400 high school students indicates that 140 are familiar with the commercial.
   (2.a) Set up a 98% confidence interval for the population proportion of high school students who are familiar with the commercial.
   (2.b) The goal of the advertisement was to have at least 30% of high school students know the product. Can we conclude that the goal has been reached according to your result in (3.a)? Explain briefly. If we can conclude it, what is the chance of error of conclusion? (Show your calculation steps, Excel functions and their parameters you use.)

3. (10 pts) The defective rate of a component from a production line is estimated at 3%. If we want to take a sample to statistically determine the actual defective rate of the components from the production line, then what would be the minimum sample size to make the size of 95% confidence interval less than 2% (i.e., \( E < 1\% \))? Describe briefly how you derived your answer, what Excel function(s) you used and how you used the function to figure out the solution.

The average score of the test was 42.35 out of 50, or 84.7%, in the three sections of this course in the past two years in which this intensive statistics was taught. The test results showed that students were capable of doing statistical inference and hypothesis testing on population means.
and population proportions, as well as determining the required sample size. “Statistics turns out not as scary as I used to feel,” a student commented.

IV. Summary and Planning

(1) Statistics is difficult with its mathematical details for most business students. But it is conceptually simple: Statistics is to investigate a population from a sample from it. There will be chances of errors when extending the result of a sample to the population. Probability theory is therefore used to tell the chances of errors.

(2) Business students will use statistics as a tool in their career. They do not need to understand every formula and every mathematical detail of statistics.

(3) Business students are relatively weak in mathematics.

(4) We have computers to help do calculations and deal with probability distributions.

(5) As a mathematics subject, statistics is very rigorous in dealing with various scenarios. In many applications of statistics, there are inherently inaccuracies and uncertainties. Some mathematics subtleties in statistics may not be necessary for the business users. Those mathematics subtleties often not only scare away business users who are weak in math but also distract their attentions from the essential of statistics.

This two-hour-with-no-textbook review on statistics is a pilot work of renovations of teaching statistics in business field. Since the outcomes of this condensed statistics review have been encouraging, more contents are planned to be added in, such as multiple regressions.

Reference:
A Graph-Based Approach for Analyzing Student Networking in Co-Curricular Activities

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Abstract
The objective of our research is to first, identify patterns in student networks that are engaged in co-curricular activities, and second, to associate the patterns found with characteristics such as a student’s choice of a major and potential rate of attrition. For this study, we are examining social networking in the context of the Management Achievement Program (MAP) at the College of Management in University of Massachusetts Boston. MAP started in 2006 and is designed to foster engagement and build competencies for academic success. It provides the opportunity for students to personally synthesize their academic and professional goals and experiences, and at the same time, increase involvement in the College and local business communities. MAP consists of a range of activities that includes seminars, career workshops, seminars, guest speakers, on-site visits to companies, job fairs, and networking events.

MAP is a graduation requirement for all students in the college. Each MAP activity is designated with a certain number of MAP “miles” as an award for participation, and to meet the requirement, students must reach a certain number of MAP “miles”. However, students’ level of involvement and the types of activities they are attracted to both vary over time. This creates an opportunity to detect patterns of networking among students and the interests of specific groups. Hence this study proposes to utilize social network analysis to detect communities around MAP activities that students are involved in.

The data for our analysis consists of attendance records for MAP activities. We propose to create an undirected graph where the students are represented as nodes and the similarity in their MAP activities denotes the edges. We will also consider a weighted graph where a weight $w$ is assigned to each edge between pairs of nodes where $w$ is determined as a function of the number of MAP activities common between a pair of nodes and the MAP miles, which are the activities...
award for participation. The weighted graph based approach measures the strength of the similarity between nodes, and consequentially can identify cohort groups and determine the community strength.

The communities that emerge from the analysis can be associated with specific MAP activities and other underlying characteristics. For example, students in Accounting may participate in similar activities, while those in Marketing may also participate in an exclusive set of activities. In turn, these results would have the potential to be used for predictive modeling.

Our study also aims to detect if there are persistent patterns in the communities over time or if changes occur based on their underlying properties. Our study assumes that communities are characterized by complete linkages amongst a group of students represented as nodes, who attend similar activities. However, the strength of edges between nodes may vary, which could further indicate stronger ties between specific nodes. On the other hand, there is a possibility of overlaps between communities where certain nodes may fall in different communities.

The practical implications of detecting community structures can be used to target appropriate activities to a specific group of students. This in turn can be used to support student retention within academic programs by developing more specialized programs based on the strength of the communities. The results of our study also have potential use in models to predict student retention. Furthermore, the detection of overlaps amongst communities can be used to design cross-disciplinary programs within MAP as well as academic courses to attract different groups of students.
A TEST OF PURCHASING POWER PARITY AND CURRENCY EXCHANGE RATES:
SUPERMARKET PRICES IN GHANA AND THE USA

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Abstract

There have been numerous studies about Purchasing Power Parity (PPP). Some have related PPP to actual currency exchange rates. Most of the studies have used some sort of proxy for the total basket of all products. Typically a country’s Consumer Price Index is used for each of the countries that have been studied. This paper differs in that 102 actual products deemed to be exact or nearly exact products were selected for study to determine the PPP in effect for Accra, Ghana, and Maryland in the United States. The resulting PPP for the products selected and the actual currency exchange rate in effect at the time of the study were very nearly identical. Further an examination of the variability found in the data was made.

Key words: Purchasing Power Parity, Exchange Rate, Ghana, USA

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Introduction

There appears to be no rigorous product oriented investigation of the concept of purchasing power parity as it exists between Ghana and the United States. Therefore the original purpose of this study was to determine if the published currency exchange rate between the Ghanaian (new) Cedi was similar or close to the implied purchasing power rate of exchange as calculated from prices gathered in two similar retail outlets located in Accra, Ghana and in Bel Air, Maryland in the U.S.A. And, ah, the joys of studying international currency exchange rates! At the time of the initial idea of comparing the published exchange rate between the US dollar and the Ghanaian Cedi (in early June, 2015) and the implied purchasing power of the Ghanaian Cedi, the published exchange rate was around 4.33 Ghanaian Cedis needed to buy one US dollar (OANDA, 2015). Then at the time of initial analysis (In mid-July, 2015), the published exchange rate for these two currencies was 3.2 Ghanaian Cedis to the dollar (OANDA, 2015).

What happened? The answer was that the IMF released the first of payments of nearly a billion US dollars bailout deal to the Ghanaian central bank which increased its dollars sales at a rate of $20 million per day (Ghanaweb; 2015). By August 10, 2015, the Ghanaian Cedi had declined to a more normal 3.7 Ghanaian Cedis to the US dollar (Oando.com; Aug 10, 2015).

Another goal of the paper was to invert the idea of the Economist’s Big Mac Index from one product (The Big Mac hamburger sandwich) in many countries (Economist; 2016) to many (102) products in two countries. “THE (sic) Big Mac index was invented by The Economist in 1986 as a lighthearted guide to whether currencies are at their “correct” level. It is based on the theory of PPP, the notion that in the long run exchange rates should move towards the rate that would equalise the prices of an identical basket of goods and services (in this case, a burger) in any two countries” (op.cit). Thus a total of 102 products ranging from produce (oranges), branded
products (Beefeater gin), local house brand products (Rite Brand, Giant brand), to generic products with no brand (cotton puffs) were selected for this paper. Several “Shoprite” supermarkets in Accra, Ghana, and the Giant Foods store located in Bel Air, Maryland, USA were the main sources of food prices.

The major questions to be answered revolved around the published currency exchange rate between the Ghanaian new Cedi, and the US dollar as well as a close study which, how, and why certain individual products varied from the hypothetical implied purchasing power rate of money exchange.

**Conceptual Framework**

**Purchasing Power Parity Theory.** Purchasing power parity (PPP) is said (by Balabkins and Gunter; 2001) to have been first proposed by Gustav Cassel who is said by the same authors to have stated, “… the rate of exchange between two countries will be determined by the quotient between the general levels of prices in the two countries” (cf. Cassel; 1916). In most investigations of purchasing power parity a surrogate for actual product prices is used to compare the two countries (Hassan, Hoque, and Koku; 2014, Ward; 2002). The method is named the “unit root test”. Hassan et al (2002) used the Consumer Price Index of the United States compared to the similar (if not identical price indices from five South Asian countries. Sadoveanu and Ghiba (2012) used the same methodology to measure purchasing power parity in the Czech Republic, Hungary, Poland and Romania.

**PPP Problems.** The idea behind purchasing power parity is that the price of a product found in one country should be the same in another country if the currency rate of exchange is fair. Kargbo (2003) correctly raised the problem that “…the PPP theory stems from its lack of a precise mechanism by which exchange rates are linked to prices…”. (Oguanobi, Chukwu, et.al;
2010) suggest that other problems such as transportation costs and other barriers to trade may impede complete purchasing power parity.

**The Big Mac Index.** The big Mac Index was invented by the Economist magazine in 1986 (economist.com; 2016). The Big Mac Index compares the local price of a Big Mac sandwich in the other country multiplied by the US dollar exchange rate in effect at the time with the price of the Big Mac sandwich found in the United States. This index has been very popular and is published every year by the Economist magazine. It shows considerable variability in the local Big Mac prices compared with the US Big Mac price.

**An Inverse Approach.** Considering the idea that the general level of prices in each country should approximate the rate of exchange between each country studied, a fairly large selection of products from Ghana and from the United States should be roughly equal to published exchange rates between the two countries. This forms the basis for the main economic hypothesis:

1. *The mean prices of products studied each in Ghana and the United States should be the same as the published exchange rate for the two countries.*

Clearly the PPP rate of exchange for each product studied is not likely to be the exact mean PPP rate of exchange for all the products considered. Just as the Big Mac Index shows considerable variability among the nations surveyed, it can be expected that there might be considerable variability among the products surveyed in this study. This forms the basis for the second hypothesis:

2. *There is considerable variability among the individual products prices as surveyed in Ghana and the United States.*

What is of interest is the identification of those products which do not show closeness to the overall mean PPP exchange rate.
Methodology

Stores selected. The prices were gathered in Accra, Ghana during the month of June and early July, 2015 in the United States. The prices were found at several Shoprite locations in Accra. Most of the prices were found at the “Accra Mall”. Some of the prices were found at the Shoprite locations in “West Hills Mall”, and the “Oxford Street Mall” also located in Accra. Shoprite was the only supermarket location in Accra that would match well with similar locations in the US. Shoprite appeals to upscale customers and locates its stores in upscale locations. It was noticed that each Shoprite location carried somewhat different ranges of products from other Shoprite locations. Shoprite is a South African headquartered chain of supermarkets. The following is a picture of the two supermarket locations selected for the study.

The corresponding US supermarket selected for study was the Giant Food supermarket located in Bel Air, Maryland, USA. As with the Shoprite supermarkets in Accra, the Giant Food supermarkets appeal to an upscale group of consumers. In some cases, the selected Giant supermarket did not carry items found in the Shoprite locations. For example, individual “Snickers” brand candy bars, individual cans of Coca Cola, Tylenol pain reliever, cigarettes, and alcoholic whiskey and gin were not found in the selected Giant supermarket. They were found at nearby retail stores that did carry these products (Wawa convenience stores, Rite Aid stores, and a local liquor store).

It should also be noted that “Shoprite” stores found in Africa are not affiliated with the “Shop Rite” stores found in Maryland.

Products selected. The products selected were primarily those that could be found in both countries. For example, Coca Cola, Kellogg’s Corn Flakes, Johnson & Johnson baby oils and shampoos, Duracell and Energizer batteries, and many other branded products could be found for
sale in both country’s supermarkets. In addition, Shoprite stores had their own “in house” brand, Rite” brand, available for sale as suitable value replacements for world brand products. Some of these “Rite” brand products were selected. Similarly, “Giant” brand, house brand products were included. In most cases there were highly similar products offered for sale in both countries, but were not “world” brand products. The “Rhodes” brand of jellies and jams offered in Shoprite compare very favorably with the “Smuckers” brand offered in Giant Foods. Similarly, “Simba” brand potato chips (made by Pepsico) are popular alternatives to “Lay’s” potato chips (which were included). Utz brand potato chips, a popular local brand of potato chips found in Giant supermarkets were included also. Certain produce, oranges, tomatoes, potatoes, and other similar produce items were selected. The senior author evaluated the items and considered those chosen to be exact or nearly exact equivalents, albeit from very different sources. The selected products are enumerated in the attached appendix.

Data Examination and Cleaning. The main purpose of this paper at the start was to determine if the published currency rate of exchange Ghanaian Cedi to the dollar (at the time of data collection) compared closely to the implied purchasing power rate of exchange as calculated from the 104 products selected for analysis. For purposes of graphic display and subsequent analysis, the largest two outlier products were excluded (Energizer 9 volt battery, and the Gillette Mach 3 razor).

Analytical Methods. Statistical Program for the Social Sciences (SPSS) version 22 was used on the data. Some of the methods were bivariate correlation, and cluster analysis. Unit prices for each case were calculated. In some cases the package container was denominated in grams in one country and milliliters in another. In cases where it was deemed reasonable one gram was equated to one milliliter (toothpaste). There were four statistical methods to compare the
structure (eg. Ranking of product prices) of the prices found in Shop Rite, Accra with the prices found in the Giant Food: Pearson’s Correlation Coefficient, Cronbach’s Alpha, Kendall’s tau_b, and Spearman’s rho.

**Results**

**Implied Purchasing Power currency exchange rate.** The implied purchasing power exchange rate for the 102 products selected for the study resulted in a mean implied purchase exchange rate of 4.42 Ghanaian Cedis to the US dollar. The published exchange rate of the Ghanaian Cedi to the US dollar at the time of the study was 4.33 Ghanaian Cedi to the US dollar (op.cit). The mean implied purchase exchange rate for all products (including the two outlier products) was 5.52.

If one were to total the unit prices for the selected Ghanaian priced products and divide by the total unit prices for the US priced products to obtain an implied purchasing power of the US dollar when compared to the US products, the implied purchase exchange rate would be 3.52 Ghanaian Cedis to the dollar.

The cost to obtain a basket of the total products at Shoprite was 1,801.70 Ghanaian Cedis. The similar cost to obtain the products at Giant Food was $446.45. Using this (admittedly somewhat odd) basis for calculating the implied purchasing power of the US dollar compared to the Ghanaian Cedi resulted in an exchange rate of 4.04 Ghanaian Cedis to the US dollar.

**Pearson Correlation Coefficient.** The Pearson correlation coefficient for unit prices for all items (excluding the two outliers) was 0.640, a relatively low relationship. The Spearman rank correlation was 0.799. This is interesting in that the ranking of unit prices is significantly higher than the Pearson correlation coefficient. This means that expensive items in Shoprite, Accra, Ghana are also expensive items in Giant Food in Bel Air, Maryland, USA.
Reliability Measures. Considering the ten highest priced products, Kendall’s tau_b is 0.966, Spearman’s rho is 0.991, and Cronbach’s alpha (based on standardized prices) is 0.958. For the ten lowest prices, Kendall’s tau_b is 0.958, Spearman’s rho is 0.906, and Cronbach’s alpha is 0.782.

Test of Normality of Cumulative Prices. It is also of value to know whether the prices of the selected products are normally distributed. The Kolmogorov-Smirnov test accomplishes this. For the prices in Ghanaian Cedis, the Kolmogorov-Smirnov test value is 0.134 with a highly significance value of 0.003. The same value for the prices in US dollars, the Kolmogorov-Smirnov test value is 0.186 with a significance of 0.000. The values for the Shapiro-Wilk tests are 0.889 and 0.795 both with significance levels of 0.000. The figures below describe the cumulative values for the Ghanaian Cedi and the US dollar.
Figures Two and Three
Normal Q-Q Plots of the Ghanaian Cedi and US Dollar Prices

The data used for this analysis is shown in Appendix One.

**Highest/Lowest Priced Products in Ghana and the US.** The following tables displays the lowest and highest priced products in Shoprite, Ghana, and Giant Food, US.

### Table One
Lowest Priced Products in Ghana

<table>
<thead>
<tr>
<th>Product type</th>
<th>Brand name</th>
<th>container</th>
<th>measure</th>
<th>quantity</th>
<th>price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salt</td>
<td>“Rite” house brand</td>
<td>Bag</td>
<td>g</td>
<td>500</td>
<td>0.79</td>
</tr>
<tr>
<td>baguette</td>
<td>Aunties</td>
<td>Ea</td>
<td>cm</td>
<td>41</td>
<td>0.99</td>
</tr>
<tr>
<td>noodle mix</td>
<td>Indo Mie</td>
<td>package</td>
<td>g</td>
<td>70</td>
<td>0.99</td>
</tr>
<tr>
<td>baguette</td>
<td>Aunties</td>
<td>Ea</td>
<td>cm</td>
<td>41</td>
<td>0.99</td>
</tr>
<tr>
<td>garlic</td>
<td>loose</td>
<td>loose</td>
<td>g</td>
<td>1,000</td>
<td>1.39</td>
</tr>
<tr>
<td>noodles</td>
<td>Roha</td>
<td>package</td>
<td>g</td>
<td>85</td>
<td>1.49</td>
</tr>
<tr>
<td>dry soup</td>
<td>“Rite” house brand</td>
<td>package</td>
<td>g</td>
<td>60</td>
<td>1.99</td>
</tr>
<tr>
<td>dry soup</td>
<td>Knorr beef and veg</td>
<td>package</td>
<td>g</td>
<td>60</td>
<td>2.49</td>
</tr>
<tr>
<td>cola</td>
<td>Coca Cola</td>
<td>can</td>
<td>ml</td>
<td>330</td>
<td>2.79</td>
</tr>
<tr>
<td>baby shampoo</td>
<td>Johnson &amp; Johnson</td>
<td>bottle</td>
<td>ml</td>
<td>50</td>
<td>2.99</td>
</tr>
</tbody>
</table>
### Table Two
Lowest Priced Products in the US

<table>
<thead>
<tr>
<th>Product type</th>
<th>Brand name</th>
<th>container</th>
<th>measure</th>
<th>quantity</th>
<th>price</th>
</tr>
</thead>
<tbody>
<tr>
<td>Salt</td>
<td>Giant</td>
<td>Bag</td>
<td>g</td>
<td>737</td>
<td>0.69</td>
</tr>
<tr>
<td>peas</td>
<td>Giant</td>
<td>Can</td>
<td>g</td>
<td>425</td>
<td>0.79</td>
</tr>
<tr>
<td>vinegar</td>
<td>Giant</td>
<td>Bottle</td>
<td>ml</td>
<td>5</td>
<td>0.99</td>
</tr>
<tr>
<td>vinegar</td>
<td>Giant</td>
<td>Bottle</td>
<td>ml</td>
<td>5</td>
<td>0.99</td>
</tr>
<tr>
<td>potato</td>
<td>No brand</td>
<td>Loose</td>
<td>g</td>
<td>454</td>
<td>0.99</td>
</tr>
<tr>
<td>spaghetti dry</td>
<td>no brand</td>
<td>Box</td>
<td>g</td>
<td>454</td>
<td>0.99</td>
</tr>
<tr>
<td>cola</td>
<td>Coca Cola</td>
<td>Can</td>
<td>ml</td>
<td>355</td>
<td>0.99</td>
</tr>
<tr>
<td>powdered sauce</td>
<td>Knorr Pasta</td>
<td>Bag</td>
<td>g</td>
<td>121</td>
<td>1.00</td>
</tr>
<tr>
<td>powdered sauce</td>
<td>Knorr Pasta</td>
<td>Bag</td>
<td>g</td>
<td>121</td>
<td>1.00</td>
</tr>
<tr>
<td>dry split peas</td>
<td>Giant</td>
<td>package</td>
<td>g</td>
<td>454</td>
<td>1.09</td>
</tr>
</tbody>
</table>

### Table Three
Highest Priced Products in Ghana

<table>
<thead>
<tr>
<th>Product type</th>
<th>Brand name</th>
<th>container</th>
<th>measure</th>
<th>quantity</th>
<th>price</th>
</tr>
</thead>
<tbody>
<tr>
<td>cigarette</td>
<td>Rothman King Size</td>
<td>Box</td>
<td>ea</td>
<td>20</td>
<td>119.80</td>
</tr>
<tr>
<td>dry dog food</td>
<td>Pedigree</td>
<td>Bag</td>
<td>g</td>
<td>8000</td>
<td>95.99</td>
</tr>
<tr>
<td>Gin</td>
<td>Beefeater</td>
<td>Bottle</td>
<td>ml</td>
<td>1000</td>
<td>70.99</td>
</tr>
<tr>
<td>pain killer</td>
<td>Tylenol 500 mg</td>
<td>Box</td>
<td>ea</td>
<td>100</td>
<td>70.00</td>
</tr>
<tr>
<td>pain killer</td>
<td>Tylenol 500 mg</td>
<td>Box</td>
<td>ea</td>
<td>100</td>
<td>70.00</td>
</tr>
<tr>
<td>scotch</td>
<td>J&amp;B</td>
<td>Bottle</td>
<td>ml</td>
<td>1000</td>
<td>59.99</td>
</tr>
<tr>
<td>diapers</td>
<td>Pampers</td>
<td>Small</td>
<td>ea</td>
<td>36</td>
<td>54.99</td>
</tr>
<tr>
<td>tomato cheese</td>
<td>no brand</td>
<td>Loose</td>
<td>g</td>
<td>1000</td>
<td>49.99</td>
</tr>
<tr>
<td>camembert cheese</td>
<td>President</td>
<td>package</td>
<td>g</td>
<td>125</td>
<td>36.99</td>
</tr>
<tr>
<td>dog food dry</td>
<td>Purina Alpo</td>
<td>Bag</td>
<td>g</td>
<td>1750</td>
<td>29.99</td>
</tr>
</tbody>
</table>
### Table Four

**Highest Priced Products in the US**

<table>
<thead>
<tr>
<th>Product type</th>
<th>Brand name</th>
<th>container</th>
<th>measure</th>
<th>quantity</th>
<th>price</th>
</tr>
</thead>
<tbody>
<tr>
<td>scotch</td>
<td>J&amp;B</td>
<td>Bottle</td>
<td>ml</td>
<td>1,752</td>
<td>36.99</td>
</tr>
<tr>
<td>Gin</td>
<td>Beefeater</td>
<td>Bottle</td>
<td>ml</td>
<td>750</td>
<td>17.99</td>
</tr>
<tr>
<td>razor blades</td>
<td>Gillette Mach 3</td>
<td>Package</td>
<td>ea</td>
<td>5</td>
<td>15.99</td>
</tr>
<tr>
<td>washing powder</td>
<td>Tide</td>
<td>Box</td>
<td>g</td>
<td>2,720</td>
<td>14.29</td>
</tr>
<tr>
<td>dry dog food</td>
<td>Pedigree</td>
<td>Bag</td>
<td>g</td>
<td>6,800</td>
<td>13.99</td>
</tr>
<tr>
<td>diapers</td>
<td>Pampers</td>
<td>Swadler</td>
<td>ea</td>
<td>32</td>
<td>8.99</td>
</tr>
<tr>
<td>diapers</td>
<td>Huggies</td>
<td>Small</td>
<td>ea</td>
<td>32</td>
<td>8.99</td>
</tr>
<tr>
<td>hangers</td>
<td>no brand</td>
<td>Ea</td>
<td>ea</td>
<td>5</td>
<td>7.99</td>
</tr>
<tr>
<td>battery</td>
<td>Duracell</td>
<td>Package</td>
<td>ea</td>
<td>6</td>
<td>7.49</td>
</tr>
<tr>
<td>battery AA</td>
<td>Energizer</td>
<td>Package</td>
<td></td>
<td>8</td>
<td>7.49</td>
</tr>
</tbody>
</table>

The following two charts display the unit prices found in Ghana with the unit prices found in the US.

**Figure four**

*Comparison of Unit Prices Gh Cedi / US Dollar*

*Two highest outliers excluded*
Figure Two (below) shows a chart of unit prices with an approximate value of less than 0.12 in Ghana compared with unit prices in the US.

![Figure Five](chart.png)

**Figure Five**

Comparison of Unit Prices Gh Cedi / US Dollar

Only values below 0.100

**Discussion**

**Currency Rate of Exchange**

What exactly does the term “equal” mean? The mean implied purchasing power rate of exchange for the product studied was 4.42 Ghanaian Cedis to the US dollar and the published exchange rate was 4.33. It seems that the term “equal” may be translated as “substantially equal”! In this case Hypothesis One is supported. Perhaps it should be noted that one cannot simply do an analysis of variance of the “two” exchange rates.
Retail Stores Selected

The senior author visited and gathered the prices in each of the locations mentioned in the Methodology section. To him, the interior of each retail stores were substantially the same. However, it is quite clear that the Shoprite retail stores in Accra, Ghana catered to wealthier clientele than does the Giant Food Store in Bel Air, Maryland. However, the Giant Food Store in Bel Air is considered by local people to be upscale to other competitive food stores in the vicinity.

Product Selected

Reliability Measures. Using a straight comparison of the ten highest, and the ten lowest priced product in Ghana with the exact (or nearly exact) product found in the US can be measured by Kendall’s tau, Spearman’s rho, and Cronbach’s alpha. In each case (ten highest, ten lowest) the values were in the high 0.90’s. This indicates that the products selected were quite equivalent. Spearman’s rank coefficient showed that the ranking of the products in terms of price was approximately the same (0.80). A test of normality of the two series of product prices shows that the products were both normally distributed around the mean.

As with the stores selected, it is the senior author’s opinion that the products selected for the study are exactly or nearly exactly the same in product characteristics. In many cases, the products were exactly the same (cf. Johnson & Johnson baby products, Duracell batteries, Coca Cola, Alpo dog food, Beefeater Gin, etc.). Where they were not exactly the same, the senior author thinks that they were substantially the same (cf. Shell gasoline (petrol), Heinz vs Hellman mayonnaise, various produce (oranges, potatoes), meats (pork chops), etc).

Product / Price Comparisons. The most interesting part of the study is the comparison of individual products priced in each country. It is clear that some products were priced very high
or very low in the two countries. Look to Figure Four. In terms of the highest product prices, it is clear that Duracell batteries command a much higher than expected price in Ghana than they do in the US. While high priced, Gillette shaving blades are more costly in the US than in Ghana. There is more variety among the lowest priced products (Figure Five). Generic cotton puffs, and Werther’s candies are relatively more expensive in Ghana than in the US. McVites shortbread, and Knorr soups are more expensive in the US. These observations supports out second hypothesis.

**Conclusion**

Several conclusions can be drawn from this study. Firstly, the implied purchasing power rate of currency exchange as measured by the 102 products selected shows that it was quite similar to the published currency exchange rate for the Ghanaian Cedi and the US Dollar. Secondly, it can be shown that the highest priced products found in the study were very nearly the same in both countries. The lowest priced products found in the study were also very nearly the same products in both countries. And thirdly, it can be shown that some products were higher priced (or lower priced) in each country.
List of References


Appendix One

Data used for analysis
Northeast Decision Sciences Institute 2017 Annual Conference

A Test of PPP and Currency Exchange Rates: Ghana and the US
Price comparisons Shoprite Accra and Giant Food Bel
Shoprite Accra EXCLUDING two outliers
product type
brand
measureqty
price
baby oil
Johnson & Johnson
ml
300.00
12.99
baby shampoo
Johnson & Johnson
ml
50.00
2.99
baguette
Aunties
cm
40.64
0.99
bandage
BandAid assorted
ea
25.00
17.99
battery
Duracell AA
ea
2.00
19.99
battery
Duracell AAA
ea
2.00
16.99
battery AA
Energizer
ea
4.00
13.99
beer
Heiniken
ml
330.00
4.49
bleach
Rite brand house
ml brand 750.00
5.99
brownie mix
Pilsbury
g
425.00
19.99
camenbert cheese
President
g
125.00
36.99
candy
Werthers caramel
g
125.00
14.99
candy bar
Snickers
g
50.00
3.99
candy bar
Kinsbite cholate
g
50.00
3.99
candy bar
Nestle Crunch g
80.00
5.99
candy bar
Cadbury Dairy Milk
g
120.00
13.99
canola oil
Excell
ml
2000.00
28.99
cellophane tapeSellotape
meter
15.00
6.99
cereal all brankellogg
g
480.00
14.99
cereal corn flakes
Kellogg
g
500.00
12.99
chicken
no brand
g
1000.00
19.99
cola
Coca Cola
ml
330.00
2.79
cola
Coca Cola
ml
1500.00
5.99
cookies
McVites shortbread
g
280.00
10.79
Juice
Ocean Spray
ml
1000.00
12.99
cup
coffee plain
oz
12.00
5.99
diapers
Huggies
ea
8.00
9.99
diapers
Pampers
ea
36.00
54.99
diesel fue
Shell
ml
1000.00
3.37
dog food dry
Purina Alpo
g
1750.00
29.99
drink mix
Nesquik
g
250.00
11.99
dry dog food
Pedigree
g
8000.00
95.99
dry soup
Knorr beef andg veg
60.00
2.49
dry soup
Rite brand house
g brand 60.00
1.99
dry split peas no brand
g
500.00
7.49
eggs
no brand
ea
6.00
4.99
fem nampkins
Always
ea
85.00
7.49
flour
white for breadg
1000.00
7.99
gasoline
Shell plus
ml
1000.00
4.37
gin
Beefeater
ml
1000.00
70.99
ginger ale
Schweppes
ml
300.00
3.79
green pepper
no brand
g
1000.00
10.99
hand soap
Lifbuoy
g
200.00
3.79
hangers
plastic
ea
5.00
9.99
insect spray
Raid Multi insect
ml
300.00
9.99
instant coffee Nestle Crunch g
100.00
25.99
instant coffee Rite brand house
g brand 250.00
10.99
instant drink Ovaltine
g
400.00
24.99
instant oatmealQuaker
g
400.00
16.99
jam
Rhodes
g
450.00
9.99
jam
no brand
g
450.00
19.99
ketchup
Heinz
g
500.00
12.99
ketchup
Rite brand house
ml brand 750.00
6.99
mayonaise
heinz
g
940.00
19.99
mayonaise
Rite brand house
g brand 350.00
6.99
noodle mix
Indo Mie
g
70.00
0.99
noodles
Roha
g
85.00
1.49
orange
no brand
g
1000.00
14.99
paper computer no brand
96.76 500.00
29.99
paper plates
no brand
ea
20.00
5.99
peanut butter Rite brand house
g brand 400.00
9.99
peas
Rite brand house
g brand 410.00
3.99
pen
Bic
ea
2.00
5.99
pen
no brand
ea
2.00
2.99
pork chops
no brand
g
1000.00
27.99
potato
no brand
g
1000.00
4.99
potato chips
Lays
g
125.00
6.49
potato chips
Simba (Pepsi) g
125.00
3.99
puffs cotton
no brand
ea
50.00
4.99
razor
Bic
ea
5.00
9.49
razor blades
Gillette mach 3ea
2.00
4.49
rice
Rite brand house
g brand
1000.00
9.99
salt
Rite brand house
g brand 500.00
0.79
Worcestershire Colemans
sauce
ml
125.00
3.49
scent
Glade
ml
180.00
6.99
scotch
J&B
ml
1000.00
59.99
shampoo
Pantene
ml
400.00
29.99
sliced peaches Rite brand house
g brand 240.00
6.99
snack chips
Doritos
g
150
5.99
soup
Heinz mushroom g
400.00
8.99
spaghetti dry no brand
g
500.00
4.99
sugar
Energy
g
1000.00
6.99
sugar
Domino
g
500.00
7.49
tea bags
Lipton
bags
100.00
14.99
toilet paper
Rite brand house
ea brand 4.00
14.49
tomato
no brand
g
1000.00
49.99
tothpaste
Colgate Max
ml
100.00
4.49
tuna fish solidStarkist
g
195.00
7.99
washing powder Rite brand house
g brand
1000.00
11.99
washing powder Ariel
g
1000.00
18.99
washing powder Weikfield
g
450.00
11.99
whisk
no brand
ea
1.00
8.99
garlic
loose
g
1000
1.39

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Air
Giant Food Forestville
Unit
Price
exchange
brand
measureqty
pric
Gh Cedi US dollar
rate
Johnson
ml
414.00
4.49
0.043
0.011
3.99
Johnson
ml
444.00
4.49
0.060
0.010
5.91
No brand
cm
65.00
1.99
0.024
0.031
0.80
BandAid assorted
ea
30.00
4.49
0.720
0.150
4.81
Duracell
ea
2.00
4.49
9.995
2.245
4.45
Duracell
ea
6.00
7.49
8.495
1.248
6.81
Energizer
8.00
7.49
3.498
0.936
3.74
heiniken
ml
650.62
2.61
0.014
0.004
3.39
Giant
ml
887.00
1.29
0.008
0.001
5.49
Betty Crocker g
523.00
2.79
0.047
0.005
8.82
President
g
226.00
6.99
0.296
0.031
9.57
Werthers caramel
g
155.00
2.79
0.120
0.018
6.66
Snickers
g
52.70
1.29
0.080
0.024
3.26
Hershey
g
43.00
1.29
0.080
0.030
2.66
Nestle Crunch g
43.00
1.29
0.075
0.030
2.50
Cadbury Dairy Milk
g
113.00
1.79
0.117
0.016
7.36
Wesson
ml
710.00
2.99
0.014
0.004
3.44
Scotch
m
20.30
1.89
0.466
0.093
5.01
Kellogg albran g
519.00
4.29
0.031
0.008
3.78
Kellogg corn flakes
g
340.00
2.99
0.026
0.009
2.95
Giant
g
453.60
6.78
0.020
0.015
1.34
Coca Cola
ml
355.00
0.99
0.008
0.003
3.03
Coca Cola
ml
2000.00
1.99
0.004
0.001
4.01
Walkers
g
150.00
3.99
0.039
0.027
1.45
Ocean Spray
ml
1890.00
2.99
0.013
0.002
8.21
coffee
oz
12.00
1.99
0.499
0.166
3.01
Huggies
ea
32.00
8.99
1.249
0.281
4.44
Pampers
ea
32.00
8.99
1.528
0.281
5.44
Shell
ml
3785.00
2.75
0.003
0.001
4.64
Purina
g
2000.00
5.49
0.017
0.003
6.24
NesQuik
g
618.00
4.99
0.048
0.008
5.94
Pedigree
g
6800.00
13.99
0.012
0.002
5.83
Knorr veg
g
40.00
1.69
0.042
0.042
0.98
Giant
g
127.00
1.19
0.033
0.009
3.54
Giant
g
454.00
1.09
0.015
0.002
6.24
no brand
ea
6.00
1.89
0.832
0.315
2.64
Always
ea
120.00
6.29
0.088
0.052
1.68
Pillsbury whiteg for bread
1000.00
2.26
0.008
0.002
3.54
Shell Plus
ml
3785.40
3.049
0.004
0.001
5.43
Beefeater
ml
750.00
17.99
0.071
0.024
2.96
Canada Dry
ml
2000.00
1.79
0.013
0.001 14.12
no brand
g
453.59
1.98
0.011
0.004
2.52
Safeguard
g
452.00
3.99
0.019
0.009
2.15
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Glade
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Domino
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Giant
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no brand
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Colgate MaxFresh
ml*
170.00
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Starkist
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Redners
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Tide
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2720.00
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Gain
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779


HOW SHOULD “SUPPLY CHAIN ANALYTICS” BE MEASURED IN SURVEY-BASED RESEARCH?

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ABSTRACT

Researchers and practitioners (e.g. Kiron and Shockley 2011; McAfee and Brynjolfsson 2012; Waller and Fawcett 2013) claim that the use of big data and analytics (BDA) drives superior firm performance and competitive advantage. Yet, empirical research establishing such relationships is as at a nascent stage.

As indicated by the usage of prefixed phrases such as “customer analytics”, “social media analytics” and “people analytics”, BDA is portrayed as broadly applicable to many problem domains. The application of BDA within the domain of supply chain management or supply chain analytics (SCA) is relevant to both operations management (OM) and information systems (IS) researchers and is the context of this session along with a focus on survey based-research. Specifically, this session will facilitate a discussion about alternative conceptualizations and operational definitions of SCA.

First, the discussion will be framed by briefly reviewing survey-based research from two literature bases: 1) research related to SCA and business analytics (e.g. Chae et. al. 2013, Chen et. al 2015, Trkman et al. 2010) and 2) research within both IS and OM disciplines that has evolved under the umbrella of the resources based view of the firm (for reviews, see Wade and Hulland 2004; Hitt et. al. 2016). The latter research has relied on capabilities as a key theoretical construct and has demonstrated benefits of synergistic relationships between IS and OM capabilities (e.g. Rai et. al 2006; Setia and Patel 2013). This synergism is especially relevant for the study of SCA which is located at the intersection of IS and OM.

Second, examples of construct definitions are selected from this literature to illustrate different components of a “Unifying Framework for Business Analytics” developed by Holsapple and colleagues (2014). These examples will motivate key discussion questions including: what is different about SCA and what is the same as previously defined capability constructs? Are differences a matter of kind or a matter of degree? Are new theoretical constructs needed or should existing constructs be refined? How should constructs be defined to ensure continuity between past and future research and to discern substantive changes in organizational practices over time?

The study of SCA is an exciting new research frontier with promising avenues of investigation. This session is intended to engender a lively conversation about how to ensure cumulative knowledge creation by a community of scholars and will be especially interesting for researchers considering or currently exploring the use of SCA in organizations through survey-based research.

References


Northeast Decision Sciences Institute 2017 Annual Conference

Monte Carlo Approach to Study the Volatility of Financial Time Series Data

Abstract

New York, New York
St. John’s University of New York

Jae Lee
uses several stochastic GARCH models to show how to apply MCMC to study volatility of financial time series and to compare performance of different MCMC approaches.

Keywords: Financial Time Series, GARCH, State Space Model, MCMC, Kalman filter
Probability models show that most NFL head coaches are far too conservative in play calling, resulting in decreased win expectation values for their teams. We examine quantitative evidence that NFL head coaches should more frequently attempt fourth down conversion, attempt onside kicks, and attempt two point conversions. Old school NFL coaches like the recently terminated Rex Ryan are closed-minded, make poor play calling decisions, and have less winning percentages relative to certain open minded and successful coaches like Bill Belichick of the New England Patriots. We present evidence to back these assertions.

Andrew Perry
Springfield College
The Application of Predictive Analytics to a Direct Mail Marketing Campaign

Predictive analytics is applied to a real-world direct-mail marketing data set, for the purpose of maximizing profit.

We demonstrate how careful application of the latest analytical techniques can decrease costs by (a) identifying which contacts are the most profitable, (b) identifying which are the least profitable, and (c) ignoring those contacts which are the least profitable.

Techniques include neural networks, classification and regression trees, linear regression, and other methods. Further model enhancement is performed using customer segmentation, model voting, propensity averaging, boosting, and bagging.

The result is a double-digit percentage increase in the bottom line.
WHAT'S MISSING IN INTRO STATS? MISSING DATA.

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ABSTRACT

Statistics textbooks at the introductory undergraduate level have made great strides in incorporating real and realistic data sets. This is in line with the original and recently-revised Guidelines for Assessment and Instruction in Statistics Education (GAISE) college reports. As we know, real data is frequently messy, flawed, and incomplete. At the same time, there is a tendency to present students with assignments and examples in which data sets have been sanitized and tidied up. This creates a serious misimpression of the challenges of working with real-world data.

In particular, we can and should do better on the subject of missing data. It is surely prevalent, and missingness is a fascinating and potentially serious obstacle on the way to meaningful analysis. In this presentation, I will review several issues surrounding missing data, and demonstrate ways to incorporate (a) awareness of its prevalence and (b) accessible methodologies for ameliorating the damaging effect.

Missing data, introductory course, GAISE, real data, imputation

INTRODUCTION

In the poem Antigonish, Hughes Mearns wrote:

Yesterday, upon the stair,
I met a man who wasn’t there
He wasn’t there again today
I wish, I wish he’d go away...

Academics and practitioners know all too well that real datasets are rarely ready for analysis, yet when we use real or realistic data in our classrooms and assignments, we generally insulate students from the vicissitudes of messy or dirty data. Despite the prevalence and diversity of issues that must be addressed before analysis, we tend to sidestep such issues. Not only do we avoid them, our textbooks tend to be silent on their very existence.

To the extent that we don’t at least call attention to concepts like data errors, inconsistent keys across tables, sparse matrices and missing data, we do a disservice to our students. As the current thinking about statistics education continues to shift are from mechanical calculation in favor of conceptual understanding, and as modern technology and real data continue to enter the classroom, it is increasingly important that we shed some light on at least some of the most common problems that arise in raw data. This paper focuses on ways that we might introduce undergraduates to the root causes and implications of missingness, and at least point to some of the ways to avoid and address the problems.
Much as we wish, we wish missing data would go away, it will likely be there tomorrow.

STATISTICS EDUCATION: KEEPING IT REAL

The arguments for including real, or at least realistic, data sets in the introductory course have been recited numerous times in the past 25 years or more [2], [5], [7], [17], [21] and probably need no repetition here. Real data and authentic problem-solving can engage students in active learning, but often can lead to stumbles and frustration when the real data isn’t well-behaved.

We try to do a great deal in an introductory course, and surely the available software can free up some space to incorporate additional topics or more depth. One might argue about which topics should be “next up,” but missingness should not be missing from the list of candidates.

When teaching the concept of a distribution, texts typically cover extreme observations (outliers) for quantitative data, but are much less likely to discuss observations that are unusual due to their absence. We may cover representativeness or bias in sampling methods, less likely to spend time on situations where survey respondents answer some questions but not others. We might note the presence of NAs in categorical data, but not what to do with or about them when it’s time to interpret a crosstab.

Some common data obstacles

Data analysis and modeling require raw data in digital form. At some point in the investigative process, a person or an automated sensor captured data from a real world event or entity and entered and recorded it digitally. One can introduce students to the possibility of missingness at the point of data capture: a sensor fails temporarily, a government agency suspends data collection for a given series, a survey respondent skips or refuses to answer a question. The explosive growth of big data and the attendant career opportunities [13] are reason enough to spend some time in a statistics course on the imperfections that are the norm in real data. A first course would do well to at least comment on the importance of data cleaning in the modern practice of data analysis [4], [6], [14], [15], [18]. These are things that students can understand and can bring life to an example or to a class discussion.

Some investigators are in a position to develop, gather, and structure data from scratch, while others may avail themselves of digital data that was gathered and stored by others. For some studies, the necessary data may be sitting neatly in a single accessible table while for other studies the investigator must combine and cull data from multiple sources. At times, the merging of tables leads to missing cells.

Whether or not missingness is a problem for a particular study depends on the analysis to be performed and the data types involved. An important phase in any study is the pre-processing stage of exploration during which we look for potential data problems. That said, when one knows which rocks to turn over the process goes more efficiently. Kandel et al. [11] describe this phase of a project as an iterative process that may send the investigator back for more or different data. The goal is to make data usable, credible, and, useful. Usable refers to getting them into a form that is suitable for the intended analysis tools. Prevalent missing observations can substantially undermine some analyses, and students deserve to know this.
Credible data are representative of the target process for the purposes of the study. This is not necessarily the same as the traditional statistical meaning of representativeness, but connotes accuracy and suitability for the particular inquiry. Here again, it is possible to enlist introductory students in a discussion of what missingness might imply in terms of credibility. Such discussions can also emphasize that the practice of statistics, especial in the decision sciences, requires both domain knowledge and an understanding of statistical methods.

As a starting point, I would suggest coverage of at least the following basic concepts with respect to missing data:

- After assembling a data table, one finds empty cells. How prevalent are they?
- Do they occur randomly or with meaningful patterns?
- If we are working with public use data that has an accompanying dictionary, how are missing data coded? Some data sources use an arbitrary missing data code like -99; a data dictionary is needed to identify such practices. Others may use a string like “NA”, which software might recognize as character rather than numeric data, so that the impact of missing data might also include the need to correct the data and modeling type for a column.
- If a model requires complete cases for all variables in the model, we can lose entire cases if there are any gaps at all across the variables. Might we infer meaning from a blank cell?
- Might we sometimes be able to impute (estimate) a suitable replacement value for a blank and thereby retain the observation?

MUCH ADO ABOUT NOTHING? [8]

What do we mean by missing data and why does it deserve attention? In the most general sense it simply refers to blank or unrecorded cells within a data table. Sometimes we know or can surmise the reasons that led to empty cells and sometimes we cannot. Sometimes, the very fact that an individual case has no value for a given column is informative in its own right. [20]

In my classes we use JMP software [10] which is particularly suitable for tasks of identifying and dealing with missing cases. The point in this exposition is that students can readily come to think about why data might be missing and what impact that can have on further investigation.

As an introductory example, consider the “Youth Risk Behavior Surveillance System” that generated the data found in the JMP Sample Data table titled Health Risk Survey. This particular iteration of the survey was taken in 2005, and researchers at the U.S. Centers for Disease control interviewed nearly 14,000 9th to 12th grade students asking a large number of questions about health and risky teen behaviors. The most current CDC User’s Guide [3] for this sample data describes its methodology as follows:

The National Youth Risk Behavior Survey (YRBS) uses a three-stage cluster sample design to produce a representative sample of 9th through 12th grade students. The target population consisted of all public, Catholic, and other private school students in grades 9 through 12. A weighting factor was applied to each student record to adjust for nonresponse and the oversampling of black and Hispanic students in the sample.
This description points to two kinds of missingness from the outset: some target populations are over- or under-represented due to the sampling method, due to fact that some people decline to be interviewed, or perhaps due to the fact that they have stopped attending school. Therefore there are individuals absent from the sample whom researchers would have wanted to include. Additionally, sampled individuals may have elected to skip some questions while answering others.

These kinds of challenges can occur in any type of data collection. Huge datasets with many columns are infamous for their sparsity – an enormous number of columns with mostly blank cells. Why is sparsity a challenge? There are a number of issues of computations inefficiency, but for the purposes of this discussion, there are two big statistical problems to tackle: bias and unknown variability. It affects both the estimator and standard errors – meaning that inference is jeopardized.

The severity of the problems depends both on the extent of missingness relative to the sample size and the mechanisms giving rise to missingness. Similarly, the choice of practical responses to missing-data issues also depend on how and why those pesky blank cells occur in the first place. In cases where the reasons for missingness are well understood, it’s no small matter to select the most appropriate approach to data preparation and analysis. When the underlying mechanism it not well understood, it is ultimately up to the analyst and subject-matter experts to decide on the assumptions they are willing to make. There is no purely statistical rationale that is valid in all studies.

A helpful framework
Depending on the available time in the course and the sophistication of students, one might introduce some of the relevant research in the area. Little and Rubin [12] differentiate among three types of missing data:

- **MCAR: Missing Completely at Random.** Blank cells occur essentially without any pattern, and the likelihood of missingness is the same for every case. Observed values provide no information about the missing values. Missingness does not depend on any observed data. A data value is missing because of a transcription or data entry error that might occur for any subject in the study. When it is justifiable to think that data are MCAR, then complete case analysis is likely to be unbiased, which is to say it is safe to simply omit rows with any missing cells.

- **MAR: Missing at Random.** The probability that an observation of Y is missing is a function of observed variables that are completely reported. When data are MAR then analytic techniques that require complete cases may yield biased estimates. In the YRBS example, if it is plausible to assume that students’ propensity to skip a question about drinking behavior does not depend on other factors such as age, we might consider NA’s for the drinking question to be MAR.

- **MNAR: Missing Not at Random.** If the pattern of missingness (not the values themselves, but the fact that they are missing) depends on unobserved data, then empty cells are missing not at random. In other words, “[e]ven after the observed data are taken into account, systematic differences remain between the missing values and the observed values.” [22]. If, for example, the fact that a student engages in a non-reported drinking behavior increases the probability that the student will skip a question about something else, the NA’s would be missing not at random. MNAR data sets generally lead to biased estimates.
Another version of MNAR would be a student who feels so unsafe at school that he or she doesn’t complete the survey.

While it is unrealistic to expect that we can or should teach imputation methods [10], we can realistically help students understand that it is important to consider the mechanisms that give rise to the blanks in a data set. Whether or not we teach them to fill in the blanks, they should be aware of the pitfalls and know that there are workarounds available.

AMONG THE MISSING

In this and the next section, I introduce an extended example inspired by a 2004 article about economic and social indicators that help to account for the fact that some countries consistently dominate the medal ceremonies at the Olympic Games [1]. Without going into all of the data acquisition phase, I present students with a more-or-less tidy [2 3] data table of Olympic medal results and selected data from the World Development Indicators [24]. The full data table contains 26 variables and 2,483 observations. To set up the example more clearly, we have data from Summer Olympic Games between 1960 and 2008 and include all of the 191 countries who participated in the Olympic movement over the 13-year period. The total N consists of 191 x 13 = 2,483. Olympic results speak to reasonably common knowledge, are gender-balanced, and don’t require deep familiarity with any particular sport or nation.

Imagine that we eventually plan to investigate the relationship between the number of medals a country wins and wealth of the country. Our dataset contains several relevant variables, and for the moment we consider three of them: Total Medals per country, GDP per capita for the year of the game, and the GINI coefficient for the year. The Gini coefficient is a measure of inequality, and hence imperfectly captures the distribution of wealth in a country.

We might start the in-class discussion with an overview of the univariate distributions (see Figure 1). It is clear in this display that two of the variables are very right-skewed, and that Gini data is relatively symmetric with multiple modes. There are outliers visible in the boxplots for the first two columns.

As we discuss the shapes, centers, and dispersion of the variables, we can easily pause to draw attention to the differing sample sizes. Among these three variables, none have a full complement of cases—not even close. A short discussion of the missing data issues can proceed something like this:

_Instructor:_ Let’s think about the TotMedals column. Remember, each row corresponds to one country in a Summer Olympics year. This is the combined number of medals won by the country, and it ranges from 1 to 170. Out of a possible 2,483 rows, we have data in 481 rows and blanks everywhere else. Why might that be?

_Response:_ A lot of countries just don’t win medals.

_Instructor:_ Ah, so is a blank cell the same as a 0? Would it be a good idea to just replace all the blanks with zeros? If we do that, would it be important to make note of the fact that we did so? [19]
Responses: {varied, until someone asks…}  Wait. Does every Olympic country participate every Summer? Is competing and losing the same as not showing up? And what about the non-IOC countries?

Whether or not that question gets resolved, it opens an important line of critical thought, and it connects the idea of missing data in a sample to a careful specification of the target population.

Figure 1: Distributions of Continuous Columns

If the discussion then moves on to next two columns, the instructor has the chance to probe for understanding of the different economic metrics and to explain a bit about varying statistical infrastructure in the nations of the world. One can also point out that Corrado Gini only developed his index in 1912, and that the World Bank did not begin routinely reporting it for developed nations in our sample until 1984. Gradually since that time, we have data for more countries but the majority of these countries simply do not have a reported figure.

Until we arrive at a point in the course where bivariate and multivariate are in play, it makes little sense to raise issues of pair-wise or case-wise deletion. However, as soon as one is ready to create a scatterplot, consider asking this question in class: Think about a country that won, say, 2 medals in 1972, but did not report GPD per capita that year. What happens to their dot in the scatterplot?
When we get to correlation, here’s a thought-provoking query: if we have 1,828 GDP values and 481 TotMedal values, how many values go into the computation of the correlation coefficient? Is it necessarily the case that the 481 medal winners all reported GDP each year?

**Exploring Missing Value Patterns**

Though this goes beyond what one might include in a first course, JMP has some relatively easy functionality to see how missing data can potentially cripple the overall sample size. An instructor can demonstrate the relevant commands if only to convey a sense of the complexity of the problems.

In the data table, there are actually nine indicators related to the wealth of the nations. Figure 2 shows the initial report on missing values for that group of columns. The key area of the report the tally of missing values toward the bottom.

If so desired, we can go a step further and generate a Missing Value clustering report and see a hierarchical graph of missing observations by column and row. Because it is a tall narrow image, I’ve rotated the view in Figure 3. Blue areas show where observations are present and red indicates missing observations. The idea in this diagram is to find groups of columns where missingness is least problematic and to know which rows are most impacted by missing data.
At the introductory level, the potentially stunning takeaway is that so few rows in the entire data table actually have data for all nine variables—a vertical strip of blue in the figure. If one someday wanted to build a statistical model that relied on all nine explanatory variables, one would jettison the vast majority of the original data. In fact, it turns out that only 191 cases (less than 8%) are complete.

As the dimensionality of a data table increases, the penalties imposed by missing cells grow. In the context of modeling, missing data can pinch us in multiple ways. For multivariable models, some methods require a full complement of observations row-wise. If the model for Y includes factors X1 and X2, we lose rows missing X1, X2 or both and this fact magnifies the impact of missing data. If we start dropping subjects (rows) from the analysis, we are likely to bias the results except under certain restrictive assumptions.

Although it would be the rare first course that actually teaches multivariable modeling, there’s no reason to avoid mention of the fact that subsequent courses will get into such fascinating models, and that practitioners use them often to investigate important questions.

More concepts to include

In a given study where data are being combined from several sources, missing data may be more or less troublesome for the ultimate user of the data than for the original constructor of the database [12]. Depending on the goals of a study, the analyst may be able to side-step some missing values, or use an analytic technique that does not require complete cases. She may be able to impute values to fill in blank cells, or use a technique that draws meaning from the fact that a cell is missing.

Unless there is reason to think otherwise, missing data is potentially problematic for two serious reasons: missing observations can lead to biased estimates, and to inaccurate estimation of sampling variability. In plainer language, models built on a foundation of sparse or incomplete datasets can (a) systematically over- or under-estimate model parameters and (b) inaccurately account for uncertainty. Hence, statistical inferences will be unreliable and decisions based on such inferences can produce undesirable and unpredictable consequences.
Although a first course probably cannot teach methods of data imputation, there is value of informing students that overcoming data obstacles is part of what statisticians and data scientists do, and that there are well-establish approaches to working with data tables that suffer from sparsity and missingness. A data set with missing data is apt to be inferior to a complete record; there are techniques that can compensate for the deficiencies in various ways, but do not render a gap-filled data table into one that is identical to one that was complete from the outset.

FOUR BASIC APPROACHES TO MISSING DATA

Little and Rubin [12] propose a taxonomy of four categories of missing-data strategies.

1. Procedures based on completely recorded units. If there are relatively few missing observations, use case-wise deletion and forge ahead. Similarly, if a variable has mostly missing values, omit it from the analysis.

2. Weighting procedures. This is common with survey data where population subgroups appear in the sample disproportionately to their occurrence in the population. Many platforms in JMP anticipate the use of sampling weights, which are often supplied with public-use survey data.

3. Imputation-based procedures. There are several methods provided in JMP and other packages to fill in blank cells with plausible estimates, and then the analyst applies methods that require complete cases.

4. Model-based procedures. These approaches involve modeling using the observed data, applying maximum likelihood methods for estimation of parameters and variability.

I would not suggest that a first course should spend time illustrating or instructing these strategies, but I do argue that it is valuable and important to communicate that (a) missingness is a serious and common problem and (b) there are ways forward. As a gentle introduction to the idea of imputation as a responsible alternative to blindly omitting observations, consider this example.

Special Considerations for Time Series

In the Olympics example, we really have panel data: a relatively stable set of 191 nations observed 13 times at regular 4-year intervals. For many of the countries in the dataset, some of the economic time series are left-censored, which is to say that these countries did not report the statistics in the earlier years under study. For example, Afghanistan’s data started in 2004, and the first 11 observations are missing. Given the political turmoil in Afghanistan for much of its recent history, it is likely to be difficult to impute plausible GDP values.

However, in countries with but a few missing values and stable rates of GDP and population growth, we might apply a simple curve-fitting technique to impute the missing observations.

Take for example per capita GDP in Bhutan in the pre-imputation raw data, depicted in Figure 5. We have just 9 of 13 possible observations, beginning in 1980. Although we do not know exactly that GDP per capita was in the years before 1980, we know it was not 0. I should also note that this example is moot, but illustrative. Bhutan competed in the Olympic Games for the first time in 1984 and did not win its first medals until the 2016 games.
If we fit a model of $\log(\text{GDP})$ vs. Year to this set of data and then save predictions, we generate plausible estimates for the first five unobserved years. Figure 6 shows the model fit as well as the imputed values.

**CONCLUSION**

Missing data presents numerous challenges, and is among the most common data preparation hurdles. This paper has presented a case for incorporating the topic in a basic introductory course, as well as some intuitive approaches to doing just that. The alternative is send students out from the course with the mistaken impression that either real datasets are typically complete, or that missing values simply don’t count.
REFERENCES


Come back home: manufacturing reshoring motivations in USA and Europe

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Abstract

Although an increasing number of research concerning reshoring phenomenon has been conducted in recent years, the extant literature suggests further exploration of reshoring motivations. Based on the literature review and secondary data (publicly available case studies), this research investigates what makes firms bring their manufacturers back and compares how their motivations for manufacturing reshoring decisions vary in USA and European countries. The results as well identify possible linkages of reshoring motivations to company/production process characteristics such as labor intensity and technology level.
Workshop

Publish Don’t Perish:
Tips that Improve Your Ability to get Published

Dr. Robert N. Lussier

Who Should Attend and Time

Today, publish or perish is now required at even teaching colleges. As much as we love to teach, publishing clearly affects the position we can attain, tenure, promotion, and pay. The workshop is intended primarily for doctoral students and junior faculty. But even full professors can find it beneficial, and professors can also give tips to other attendees. Attendees will learn how to increase their publication quality and quantity. Take-away tips relate to the following topics below that are covered during the workshop:

Format

It will be a presentation with a sharing and question and answer format. The workshop leader will cover the topics following the outline below. After the presentation of each topic, time will be allowed for questions and answers, so bring your questions. Others are encouraged to give tips and to answer and respond to other participant questions.

Topics

Foundations (developing a winning attitude and persistence—Ch 1)
Selecting Topics and Publication Sources (requirements, niche, selecting journals—Chs 2 + 5)
Matching Publication Sources (reviewers, referencing, formatting—Ch 6)
Time Management (finding the time to publish and to be more productive—Ch 7)
Multiplying Publications (coauthors, progression, mining your data, extending work—Ch 8)
Empirical Research (What to include in each part of your article—Ch 9)

Source

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The Impact of Target Characteristics on Post Mergers and Acquisitions Innovations

Simona Ileana Giura

SUNY ONEONTA
The Impact of Target Characteristics on Post Mergers and Acquisitions Innovations

Abstract

In this paper we show that sometimes post M&A innovation is increased while sometimes is decreased depending on the characteristics of target and acquirer. Technologically strong firms lose incentives when they are acquired and therefore post M&A innovation is negatively impacted. However, if the acquirer has the necessary background knowledge, the target's knowledge can be integrated and therefore post M&A innovation can be increased. In this research, we have also shown that technologically strong firms are willing to be acquired by technologically weaker firms due to financial constraints.
Introduction

A large body of previous literature has looked at the impact of M&As on firm performance. (for a review see King, Dalton, Daily, & Covin, 2004). However, although of equal importance to the M&A literature, post M&A innovation performance has received less attention.

In the post M&A innovation literature findings are conflicting. Some studies suggest that acquisitions do not enhance the innovative performance of firms (Hitt, Hoskisson, Ireland, & Harrison, 1991; Hitt, Hoskisson, Johnson, & Moesel, 1996). These studies argue that managerial resources are limited (Penrose, 1959) and that the acquisition process itself diverts resources from knowledge creation and absorption leading to a negative innovation performance. Ahuja & Katila (2001) investigate the impact of the target’s technological capabilities on the post M&A innovation and find that if the target has greater technological capabilities it will positively impact post M&A innovation. However, if the acquirer doesn’t have enough absorptive capacity to integrate the target’s knowledge, the innovation post M&A will be reduced. In a more recent study, Valentini (2012) tries to reconcile these contradicting results, and by focusing on both quantity and quality of the post M&A innovation, finds that M&As have a positive impact on the patenting quantity but a negative impact on the patenting quality.

Also, more recently studies have started looking at the impact of incentives on post M&A innovation. Kapoor & Lim (2007), find that inventors from acquired firms as compared to non-acquired firms have lower innovation productivity due to lower incentives. Puranam & Srikanth (2007) findings suggest that autonomy of the target is desired when exploration is the focus of the M&A while integration of target is desired when exploitation is the focus.
While these studies provide various insights into M&As innovations, they bring conflicting results regarding the impact of acquisitions on post M&A innovation. We try to develop a broader framework that explains why there may be both an increase as well as a decrease in innovation performance. In this paper, we look at under what conditions post acquisition innovation productivity can be increased. While we agree with Kapoor & Lim (2007) that the target’s inventors lose incentives, we argue that this is not always the case. Based on Grossman & Hart's (1986) framework, we argue that if the target is technologically weaker than the acquirer, the control of the acquirer is desirable. Consequently, in these cases, we don’t expect to see the target losing incentives and therefore post M&A innovation will be increased. On the other side, if the target is technologically stronger than the acquirer, control by the target is desirable. Although this is desirable, the residual rights are assigned in the acquisition process to the acquirer. Thus according to Grossman & Hart (1986), in these cases, there will be a loss of incentives from the target. Therefore it becomes of importance to understand the reasons why technologically stronger targets are being acquired by technologically weaker firms. We argue that due to information asymmetry, the market is not always able to provide proper incentives to the target firms and thus some technologically strong targets become financially constrained. As a result, the survival solution for these targets is to get acquired.

Our research addresses the following questions: (1) Do targets always lose incentives in post M&A innovation activity? (2) Why are technologically stronger firms willing to get acquired by technologically weaker firms? We address the above questions using a sample of 870 U.S. technological Mergers and Acquisition that happened between 1988-1996.

Our findings are as follows. First, we find that technologically stronger targets are being acquired by a technologically weaker firm when their ratio for Tobin’s Q per patents is low. In
other words the market is not able to provide the appropriate incentives and therefore they become financially constrained. Further, we find that targets contribute most to post M&A innovation when they have moderate technological capabilities, rather than low or high technological capabilities.

The remainder of the paper is organized as follows. In the next section we discuss our theory and hypotheses. Following that, we move on to the empirical analysis and describe the data sources, the sample construction, and the measures and methods used. Next we present the results. Finally, we offer concluding remarks and discuss the limitations of this study.

**Theory and hypotheses**

Acquisitions are important mechanism for having access to knowledge that is costly and difficult to create internally. A technological acquisition increases the knowledge base of the acquirer, leading to higher post acquisition innovations (Ahuja and Katila 2001). The combination of the firms’ knowledge bases creates synergies that otherwise would not be able to be achieved by either the acquirer or the target firm. When one firm acquires another, the contract should specify how the post M&A control rights are going to be allocated. However, contracts are costly to write and imperfect. Therefore, it is optimal for the acquirer to buy all the rights and thus the target loses its residual rights. The acquired firm, by losing its residual rights, will have lower incentives so that it will negatively impact the common innovation. When the target is technologically weaker than the acquirer, it has more incentives to be productive. Further, the target’s knowledge base is more easily absorbed by the acquirer. But when the target is technologically stronger than the acquirer, not only the target becomes less incentivized but also the knowledge base is more difficult to integrate in the acquirer’s knowledge. In these cases, the target perceives unfair the control of a less technologically capable firm.
As a result of the target losing its autonomy and becoming a part of the acquiring firm, its innovation performance becomes more difficult to measure and thus the target is less motivated to participate in post M&A innovations.

We expect that post M&A innovation will be positively impacted by the knowledge stock of the target up to a point where the impact becomes negative due to incentives decreasing in an acquisition as the knowledge stock increases. As a result, we hypothesize that:

**Hypothesis 1: Previous knowledge stock of a target has an inverted U shape impact on post M&A innovation.**

Markets are imperfect and innovative firms might be undervalued and thus face financial constrains. An acquisition can create value for the target firm by easing some of the financial constrains as also as for the acquirer by expanding its knowledge base. Also, some technologically strong firm don’t lack resources but they have made poor use of the resources they possess. Therefore, they might need a change that an acquisition can provide. Rather than failing, technologically stronger targets will get acquired by other firms.

For example, in 1991, Chiron Corporation acquired Cetus Corporation, one of the oldest biotechnology companies and once considered one of the most promising, in a stock transaction valued at about $600 million. Cetus suffered serious financial problems when its drug for cancer treatment, known as Interleukin-2, considered crucial to the company failed to get approval of Food and Drug Administration. Despite their large stock of knowledge, their talented scientists, their only hope for survival was being acquired. Ronald E. Cape, chairman and chief executive of Cetus and a co-founder of the company, said at a news conference "If I were to tell you that I stand here exhilarated, you'd know I wouldn't be telling the truth…We couldn't have found a better partner. We couldn't have found a better home."
Hypothesis 2: Technologically strong targets are acquired due to financial constrains.

Empirical methods

Data and Sample

It has been previously argued that not all M&As are motivated by technological reasons and some of the acquisitions may not have an impact on post acquisition knowledge transfers. Therefore, we only take into account technological acquisitions, which are those acquisitions that provide technological inputs to the acquiring firm (Ahuja & Katila 2001).

To empirically test our hypotheses, we constructed a data set comprising of mergers and acquisitions as also as patenting activities of the firms implicated in M&A activities in a wide range of industries. Thus, our main two sources are: Securities Data Company (SDC) Database, Worldwide Mergers and Acquisitions and the NBER patent database (Hall, Jaffe, & Tratjenberg, 2001). The SDC database reports information on acquisitions and is compiled from publicly available sources, including U. S. Securities and Exchange Commission filings, industry and trade publications, and news reports. The SDC database has been extensively used in previous acquisition studies. Our sample consists of mergers and acquisition, where both the target and the acquirer were classified by SDC as having the primary line of business in a high-technology industry, which happened between 1988-1996. The time frame is similar to other studies. For example Valentini (2012) uses the same time frame and argues that there are two main advantages to this time frame. First, 1996 is the beginning of the latest M&A wave. Second, no major technological changes have happened it this period of time. Further, we restrict ourselves to M&As where both partners are US private or public firms. The US firm restriction is important since this is necessary to maintain consistency, reliability, and comparability, as patenting systems across
different nations vary in aspects such as application of standards, granting patents, and protection granted.

Further, we collect patent data from NBER patent database. This database has highly detailed information on patented innovations such as the technological area to which these innovations belong to, information about the inventors, the USPTO assignee names, patents cited, etc. Since our measures are based on patent data we are interested in technological acquisitions. Thus, similar Ahuja and Katila (2001), we analyzed if the target firm had any patenting activity in the 10 years preceding the M&A. If the target had no patenting activity, we concluded that it was a non-technological acquisition. Since we are only interested in technological acquisitions, we eliminated non-technological ones. The final sample after this last step is 870 M&As.

Since patents are not always assigned by USPTO to the firm subsidiaries participating in the alliance, another step we needed to take that is widely used in the patent literature was to construct a patent portfolio for alliance firms based on patents assigned to the parent as well as all of its subsidiaries (Sampson, 2007; Ziedonis, 2004). To construct the portfolio, we Who Owns Whom to identify all subsidiaries of the firms in the sample. The Directory contains information on the subsidiaries and affiliates of both public and private U.S. firms. We then drew all patents from the NBER database assigned to the parents as well as their subsidiaries and aggregated the identified patents at the corporate level to construct our measures.

We also use Compustat to collect some of the measures pertaining to the target’s valuation.
Measures

We use a number of variables based on patent data. All patents filed in US have to include citations to all existing patents that are relevant to that technology. Therefore, patents offer an outline of an organization’s knowledge creation.

Dependent variable

Post M&A innovation.

We measure each firm’s innovative output after the M&A. After the M&A some of the patents are assigned only to the acquirer while in other cases are also assigned to the target. Therefore, we look at the patents of both the target and the acquirer. Similar, to Sampson (2007) we consider that a simple patent count is a noisy measure for innovative output. Therefore, we assign a weight to each patent using forward citations made by later patents. Trajtenberg (1990) has shown that weighting patents by their citations provides a less noisy measure of innovation output than simple patent counts do. Therefore, we measure firm innovative output by a count of citation-weighted firm patents in a four-year Post M&A window, with a one year lag. We choose a one year lag since it has been shown that there is a contemporaneous relationship between R&D efforts and patenting (Hausman, Hall, & Griliches, 1984). Similar to previous research, we chose to look at the date the patent was applied for (and eventually granted) since the application date is the earliest time when we can recognize the existence of a new technology (Rosenkopf & Almeida, 2003).

In testing our second hypothesis, our dependent variable is Tobin’s Q weighted by Target’s Patent Stock. Tobin’s Q as a proxy for the value of the resources has been widely used in literature (Villalonga, 2004). We measure Tobin’s Q as the sum of market value of equity, short- and long-term debt, preferred stock at liquidating value, and the book value of convertible debt normalized...
by the book value of total assets (Perfect & Wiles, 1994). This data was found in Compustat and retrieved for the year previous to the M&A.

**Independent Variables**

We measure Target’s *Prior Knowledge Stock* as the total number of target’s patents prior to being acquired. Similar to Sampson (2007) we capture this measure by simply counting the total number of patents that a firm has applied for 5 years before the acquisition. Previous studies have argued that simple patent counts (rather than citation weighted patents) are likely a better measure of R&D inputs.

**Control Variables.**

**Acquirer’s Knowledge Stock.** Similar to We measure Target’s *Prior Knowledge Stock* as the total number of target’s patents prior to being acquired. Similar to Sampson (2007) we capture this measure by simply counting the total number of patents that a firm has applied for 5 years before the acquisition. Previous studies have argued that simple patent counts (rather than citation weighted patents) are likely a better measure of R&D inputs.

To capture the similarity in technological domains, we use the measure of *Technology Overlap* developed by Jaffe (1986) based on the angular separation of the patent class distribution vectors of the partner firms in the 5 years previous to the alliance announcement date. The firms’ distribution vectors \((F_i,F_j)\) are defined over the approximately 500 patent classes defined by the USPTO (Jaffe & Tratjenberg, 2002). Previous research has used 118 technology classes as defined by the International Patent Classification System to construct their technology diversity measure (Oxley & Wada, 2009), while others have used 49 aggregated technological sub-categories (Jaffe, 1986). By using all the approximately 500 classes provided by the United...
Stated Patent and Trademark Office we developed a more fine-grained measure of *Technology Overlap*.

The extent of the overlap among partner firms’ areas of technological expertise is then:

\[
\text{Technology Overlap} = \frac{F_i F_j'}{\sqrt{(F_i F'_i)(F_j F'_j)}} \]

where \(F_i\) is the patent class distribution vector for firm \(i\) and \(F_j\) is the patent class distribution vector for firm \(j\).

Technology overlap values vary from zero to one. The closer to zero the technology overlap is, the lower the overlap in partner firms’ areas of technological expertise and the closer the value is to one, the greater the overlap. This measure is not sensitive to the total number of a firm’s patents within a class.

**Year dummies.** Since the propensity to patent may also vary across time due to cost of patenting (Pavitt, 1984) or other reasons, we control for the year when the alliance was announced.

**Acquirer Acquisition Experience.** To capture a firm’s prior alliance experience we counted from SDC the total number of formed alliances before the alliance in our sample.

**Previous Alliance Dummy.** A previous alliance with the target impacts post M&A innovation (Porrini, 2004). Therefore we control for this with a dummy variable that equals 1 if the acquirer and the target had previously formed an alliance and equal to 0 if they have never formed an alliance.

**Statistical Methods**

The methodology we use is a negative binomial model. In this specification, since our dependent variable is based on patents, there are a high number of zero values in this variable. To

\[1\] If none of the firms has patented before the alliance, the portfolio is zero and therefore the denominator becomes zero and I get an undefined result. In order to avoid this, when the denominator is equal to 0, I have set the value of technological overlap to 0 (Sampson 2007). For complete details on how to construct this measure, see Jaffe (1986).
account for this issue we employed a negative binomial model (Hausman et al., 1984), a technique that is appropriate for overdispersed count data like ours and that is widely used in the patent literature. Overdispersion refers to the property where the variance of the estimated count exceeds its mean. The negative binomial model addresses this problem by including an error term that varies, in order to capture the overdispersion effects.

**Empirical Results**

Table 1 shows the correlation table and the descriptive statistics for the variables used at the individual firm level. As seen in this table, there are no concerns of multicollinearity.

Table 2 presents the results for the negative binomial. The main model is presented in Column (1). The dependent variable is Post M&A Citation-Weighted Patents. The coefficient estimate of Target Prior Knowledge is positive and significant while the coefficient estimate on Target Prior Knowledge Square is negative and significant. This indicates support for our first hypothesis that previous knowledge stock of a target has an inverted U shape impact on post M&A innovation.

Columns (2), (3) and (4) further tests the relationship between previous knowledge stock of the target and post M&A innovation in various subsamples. In Column (2) we have only those observations for which the target is technologically stronger. We consider a target to be technologically stronger when it has a higher number of patents than its acquirer. In this subsample, we still receive support for our first hypothesis. In column (3) we have a subsample in which the target is technologically stronger and the acquirer has a high number of patents (Acquirer Patents>Median of patents in the sample). As expected when the acquirer has a high knowledge
stock the significance of square term disappears meaning that the target patent stock has a positive impact on the post M&A innovation. So when the acquirer has high knowledge stock and high absorptive capacity they are able of integrating the target’s knowledge and create post M&A innovation. However, when the acquirer has low knowledge stock (Acquirer Patents<Median of patents in the sample) then there previous knowledge stock of a target has an inverted U shape impact on post M&A innovation (Column 4). Our purpose was to show that the relationship between knowledge stock of the target and post M&A innovation is robust in various sub samples.

To test our second hypothesis, we ran an OLS model in the subsample of technologically strong targets. Table (3) Column (1) and Column (2) show the regressions with Tobin’s Q normalized by patents stock and incoming citations respectively as the dependent variable. Our purpose here was to show that those targets that are technologically strong are being poorly valuated by the market. Our regressions show that the previous knowledge stock of the target has a negative relationship with Tobin’s Q which provides support for our second hypothesis. As a robustness check we ran the same regression for the whole sample and we found support for our second hypothesis.

DISCUSSION AND CONCLUSIONS

Research in strategy literature has shown continued interest in the impact of M&As on firm performance. Our study contributes to a debate among strategy scholar on whether post M&A innovation is increased or decreased. We have tried to explain why sometimes innovation is increased post M&A and why sometimes it is decreased. Mainly, we have argued that
technologically strong firms lose incentives when they are acquired and therefore post M&A innovation is negatively impacted. However, if the acquirer has background knowledge, the target’s knowledge can be easily integrated and therefore post M&A innovation can be increased. So the question that remains to be answered is “Why are technologically stronger firms willing to get acquired by technologically weaker firms?”. We have found that technologically strong firm are willing to be acquired by technologically weaker firms due to financial constrains.

Our results have important managerial implications. Choice of target has been an important consideration for firms and has been found to be critical in influencing acquisition successes. Our results indicate that one important criterion that managers could use in selecting partners could be the target’s knowledge stock but also their own knowledge stock. Given that this information can be identified from external sources such as patent databases, profiling of potential target firms can easily be part of the due diligence process. Given that one of the key objectives in most technological acquisitions involves learning and new competence development, explicit focus on knowledge stocks is indeed warranted, but missing in most due diligence process. In fact in most pre deal analysis the focus is much more on the complementary capabilities of the acquirer and target and the cultural proximity of the partner. While these remain important considerations in target selection, our findings highlight the importance and the potential value in examining the knowledge stocks of the target as also as the acquirer’s own knowledge.

Although our results are robust across the various subsamples, this study has its limitations. Since our measure is based on patent data, it shares some of the limitations of the patent measures. Future research could potentially replace our patent measure with more qualitative studies or with the use of survey data.
TABLE 1: Correlation Table

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<td>-0.072</td>
<td>0.029</td>
<td>-0.139</td>
<td>-0.135</td>
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<td>0.223</td>
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<td>11</td>
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<td>0</td>
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<td>0</td>
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<td>Maximum</td>
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<td>5451</td>
<td>0.951</td>
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<td>59</td>
<td>1</td>
<td>1</td>
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<td>1</td>
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<td>1266.009</td>
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<td>0.356</td>
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**TABLE 2**

Negative binomial estimates for Post M&A Innovation

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<tr>
<th>VARIABLES</th>
<th>(1) Post M&amp;A Citation-Weighted Patents</th>
<th>(2) Post M&amp;A Citation-Weighted Patents</th>
<th>(3) Post M&amp;A Citation-Weighted Patents</th>
<th>(4) Post M&amp;A Citation-Weighted Patents</th>
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<td>Acquirer Prior Knowledge</td>
<td>Technology Overlap</td>
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<td>0.001***</td>
<td>0.857***</td>
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<tr>
<td></td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.201)</td>
</tr>
<tr>
<td></td>
<td>0.001***</td>
<td>-0.000***</td>
<td>0.000</td>
<td>1.233***</td>
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<td></td>
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<td>0.000</td>
<td>0.000</td>
<td>0.199</td>
</tr>
<tr>
<td></td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.000)</td>
<td>(0.409)</td>
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<tr>
<td></td>
<td>1.050***</td>
<td>0.941***</td>
<td>0.199</td>
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<td></td>
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<td>(0.279)</td>
<td>(0.409)</td>
<td>(0.357)</td>
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<td>Year Dummies</td>
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<td>Included***</td>
<td>Included***</td>
<td>Included***</td>
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<tr>
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<td>1.008</td>
<td>1.003</td>
<td>1.108</td>
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<tr>
<td></td>
<td>(0.006)</td>
<td>(0.007)</td>
<td>(0.188)</td>
<td>(0.007)</td>
</tr>
<tr>
<td></td>
<td>8.553***</td>
<td>8.564***</td>
<td>8.980***</td>
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<tr>
<td></td>
<td>(0.238)</td>
<td>(0.340)</td>
<td>(1.294)</td>
<td>(0.355)</td>
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<tr>
<td>Observations</td>
<td>870</td>
<td>437</td>
<td>84</td>
<td>353</td>
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Standard errors in parentheses
*** p<0.001, ** p<0.01, * p<0.05, + p<0.1
TABLE 3

OLS Estimates

<table>
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<tr>
<th>VARIABLES</th>
<th>(1) Target Q/Target Patent Stock</th>
<th>(2) Target Q/Target Incoming Citations</th>
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<tr>
<td></td>
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<td>(0.000)</td>
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<td>Target Debt to Equity Ratio</td>
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<tr>
<td>Target Free Cash Flow</td>
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<tr>
<td></td>
<td>(0.000)</td>
<td>(0.000)</td>
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<tr>
<td>Target Total Assets</td>
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<tr>
<td></td>
<td>(0.000)</td>
<td>(0.000)</td>
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<tr>
<td>Target Strong</td>
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<td></td>
<td>(0.079)</td>
<td>(0.012)</td>
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<td>Year Dummies</td>
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</tr>
<tr>
<td>Industry Dummies</td>
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<tr>
<td>Constant</td>
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<tr>
<td></td>
<td>(0.606)</td>
<td>(0.089)</td>
</tr>
<tr>
<td>Observations</td>
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<tr>
<td>R-squared</td>
<td>0.165</td>
<td>0.086</td>
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</table>

Standard errors in parentheses

*** p<0.001, ** p<0.01, * p<0.05, + p<0.1
References:


A HISTORIC PERSPECTIVE ON RFID IMPLEMENTATION OVER THE PAST DECADE WITH A FOCUS ON APPAREL RETAILERS: ARE WE AT THE ‘TIPPING POINT’?

Lynn A. Fish, Canisius College, 2001 Main Street, Buffalo, NY (716) 888-2642, fishl@canisius.edu

ABSTRACT

A literature review of RFID implementation highlights the transition from a ‘local’ view towards a supply chain ‘system’ view. Benefits, limitations and barriers over the past decade are discussed. Current benefits of RFID include bullwhip reduction, inventory management improvements, the business case to support RFID and business process improvement, and the use of RFID to support omni-channel capabilities. Past limitations are changing and discussed. Factors influencing RFID adoption in the retail industry are presented.

KEY WORDS: RFID, retail, implementation

LITERATURE REVIEW

An understanding of history provides benefits to our appreciation of the past, insight into the present, and assistance in predicting the future. In order to remain up-to-date and avoid falling behind their competitors, supply chain managers need to consider the latest innovations within an industry. Radio Frequency Identification (RFID) is not a ‘new’ technology, but one that has taken more time than originally projected in 2005 to become a part of the global business environment. This literature review paper takes a historical perspective on RFID implementation over the past decade with a particular focus for the apparel industry at the retail level. The changing nature of the benefits, limitations and barriers to continued implementation are discussed. Industry experts are forecasting that RFID implementation has reached its’ ‘tipping point’ and the industry will grow rapidly in the coming years. Have we reached the ‘tipping point’? Is RFID coming to a retailer near you? We explore the current situation to RFID implementation in our closing comments.

A decade-ago, 2006: ‘RFID Growth Coming’

Projections in 2006 indicated that RFID was moving into the growth phase as the technology’s initial high-risk phase appeared to be over (Fish & Forrest, 2006). RFID implementation pioneers include the US Department of Defense, Wal-Mart, Marks and Spencer, Tesco and Gillette (Fish & Forrest, 2006). RFID integration in the fashion industry was taking hold as RFID integration improved the system and provided inter-organizational information sharing (Pigni & Ravarini, 2008). In the United States, implementation occurred at the pallet and case level (Fish & Forrest, 2007; Huber et al., 2007). At the time, recent mandates from leading companies indicated extensive use of RFID in the near future (Huber et al, 2007). Suppliers rushed to meet retail mandates through using ‘slap-and-ship’ methods that met the mandates but provided no benefits to the suppliers (Fish & Forrest, 2007).
We reported the potential benefits to RFID implementation in the retail supply chain as improved inventory management, improved customer service, and a reduction in labor, warehousing, and transportation costs (Fish & Forrest, 2006). Other reported advantages included non-line-of-sight scanning, simultaneous automatic reading of signal, enhanced visibility and forecasting, asset tracking, item level tracking, improved asset utilization, reliable and accurate, information richness, and enhanced security (Huber et al., 2007). Additionally, reports indicated that it can gather information about the environment (such as temperature, expiration and location of origin) en-route (Kraft & Mantrala, 2006). Studies, such as the University of Arkansas study of Wal-Mart, demonstrated positive results, which included a proactive pick-list process, a 16-percent reduction in out-of-stocks, a replenishment rate three times faster than non-RFID-tagged product, and an estimated cost savings exceeding $1.7 billion (Asif & Mandviwalla, 2005; Hardgrave, Waller & Miller, 2005; Watson, 2005). These studies supported the projection of RFID’s continued growth. Another researcher noted that RFID can reduce costs by 2.8-4.5% (Gaukler, 2005). Researchers noted progress in RFID implementation in different supply chains and different processes, such as warehousing, transportation, scheduling, order management, asset and inventory management (Banks, Hanny, Pachano & Thompson, 2007), traceability and visibility throughout the supply chain as well as at checkout (Chow, Choy, Lee & Lau, 2006). At the retail level, RFID improved the automatic check-out processes, increased shelf use efficiencies, reduced losses due to shoplifting and increased the usage of Point of Sale (POS) applications (Sounderpandian et al., 2007). Others found RFID benefits to the reverse supply chain depend upon the product return volatility and the duration of the reverse channel processes (Karaer & Lee, 2007).

At the time, we reported the limitations to continued RFID proliferation included: the technology immaturity and constant evolution, standards issues, operational challenges surrounding re-engineering business processes, tag costs, consumer privacy and Return on Investment (ROI) issues (Fish & Forrest, 2006). Other perceived limitations to RFID included the infrastructure cost, training requirements and costs, limited knowledge of use, deployment issues, interference limitations, cooperation requirements between supply chain partners and associated risks (Huber et al, 2007). Given the costs associated with the tags and the systems, using barcoding alongside the system as a smart label was envisioned as a backup system and to support cross-compatibility within a supply chain configuration (Huber et al., 2007). At the time researchers reported that RFID reduces or eliminates many sources of error in inventory management and visibility but not all of them (Atali et al., 2006).

Barriers to adoption in the retail industry included: cost, lack of awareness, and immaturity of RFID technology (Huber et al., 2007). Component costs, particularly tag costs, were cited as the critical factor leading to dismissal of RFID implementation (Huber et al., 2007), and one supply chain manager sighted the ‘10-cent’ tag level as the critical break-even point for tag implementation (Huber, Michael & McCathie, 2007). In 2007, a positive sign for growth occurred with the ratification of Generation-2 (Gen-2) RFID and the Electronic Product Code (EPC) standard developed by the Global Standards One (GS1) (Huber et al., 2007).

2008/2009: ‘Slow progress’
Initially, it appeared that suppliers were ‘lining up’ to join the ranks of RFID implementation (Kumar et al., 2009); however, the great recession of 2008 impacted upon continued RFID
proliferation (Hardgrave & Patton, 2016). Responders cited issues, such as tag cost, tag readability and reliability, privacy, and regular technology ‘updates’ and compatibility, as to why they did not implement RFID (Kumar et al., 2009). Researchers warned that each company needed to perform its own Return on Investment (ROI) analysis (Sarac, Absi & Dauzere-Peres, 2008), which highlighted the local focus on RFID implementation. As recently as 2008, researchers concluded that the item’s price and the fraction of demand are the largest contributors to the break-even costs for RFID tags (Kok et al., 2008). By 2009, researchers indicated that product value and demand uncertainty impacted upon the expected benefits associated with RFID implementation (Ustundag & Tanyas, 2009). Increasing product value using RFID tags, increases the total supply chain cost savings, while increasing demand uncertainty, decreases the supply chain cost savings (Ustundag & Tanyas, 2009).

However, as early as 2008, a focus on ‘system’ implementation surfaced. Researchers argued that RFID could streamline operations, strengthen customer relationships, facilitate promotional activities and allow better resource management (Moon & Ngai, 2008). By 2009, the potential to collect cross-channel customer information and to combine this information with insight into customer behaviors was noted (Ganesan, George, Jap, Palmatier & Weitz, 2009). Reports indicated that RFID was used by major retailers to speed time to market from the factory to stores, and to cut costs (Vouk, Jakovic & Markovic, 2009). Advantaged listed included reduced point-of-sale costs, reduced warehouse and distribution labor costs, inventory savings and improved inventory accuracy, elimination or reduction of counterfeit merchandise and theft, assistance in marketing efforts, and reduced out of stock conditions (Levy & Weitz, 2009). Others noted that RFID could collect and deliver real-time data that improved supply chain visibility and touched upon every facet of an interconnected supply chain (Bacheldor, 2009).

Others observed the benefits to automatic self-service stores by reducing non-value added activities (Bendavid, Lefebvre, Lefebvre, & Wamba, 2009). Additional benefits to RFID implementation including enabling process innovation and supply chain redesign towards competitive advantage and increased supply chain transparency through accurate, real-time data used in decision-making (Visich et al., 2009). Essentially, the ‘view’ was expanding towards a global supply chain perspective. However, researchers noted that benefits from RFID implementation are not equal in the supply chain and favors retailers over other members; the retailer’s cost savings is greater than other supply chain members (Jakkhupan et al., 2011;Ustundag & Tanyas, 2009).

However, in spite of the positive proof of its value to operational improvements, RFID did not reach a transformational level (Visich et al., 2009). A major limitation cited at the time was the ineffective use of the information obtained (Visich et al., 2009). It appears that the technology and market drivers to encourage adoption were not mature enough to generate the necessary momentum to encourage rapid adoption. Other commonly cited disadvantages to RFID included technical issues (privacy and security; bottleneck and read errors); economic (cost and obsolescence) (Kapoor et al., 2009), an excessive amount of data rendered that is difficult to process in a meaningful way (Illic et al., 2010) and compatibility issues between network infrastructures (Lorchirachoonkul and Mo, 2010). In keeping with past concerns, common limitations that remained were the tag cost, heavy cost investment in the RFID software and hardware systems; privacy and security concerns; standardization on a global scale and stated
clear goals to overcome item-level tagging issues and data analysis (Vouk et al., 2009), as well as technical and economic obstacles, metal and liquid environments that affected readings, a lack on international standards (frequencies between different nations differed), and implementation costs (Sarac et al., 2010). The costs for RFID implementation remain a concern, and case/pallet level tagging costs were lower than item-level tagging costs (Sarac et al., 2010).

2010/2011: Experts Project Continued Market Growth
While ABI research projected the global RFID market to exceed $8.25 billion in 2010 (ABI Research, 2010), by 2012, IDTechEx indicated that the actual value was much less, $6.98 billion (MMH, 2014). RFID was growing – just not as quickly as the experts believed it would. Accenture reported that 80% of retailers (out of 56 retailers and 589 suppliers) in North America initiated pilot studies for item-level tracking (Gorshe, Rollman & Beverly, 2012).

Common benefits to RFID implementation cited – regardless of the industry – included labor replacement through automation, cycle time reduction, enabling self-service and loss prevention (Ferrer, Dew & Apte, 2010). At the retail level, researchers noted that RFID improved product availability, and therefore, overall profitability and store performance (Gaukler, 2010). As of 2010, RFID benefits included: traceability improvement, visibility into the products and processes, increased efficiency, improved speed, improved information accuracy, a reduction in inventory losses, and management decision-making improvements through real-time information (Sarac et al., 2010). When implemented through a complete system for several products and processes and cost sharing occurred, collaboration and improved performance for the supply chain resulted (Sarac et al., 2010). Research continued to preach the benefits to a ‘system’ view of RFID implementation. Reports indicated positive results for supply chain processes with RFID implementation such as demand forecasting, production planning, inventory management and retail operations (Lin, Chen & Hsu, 2011; Ustundag & Tanyas, 2009). Researchers noted that advanced technologies could assist in forming an integrated system to achieve lean workflow as well as allow for real-time data capture, which further improved efficiencies and time reduction (Lee, Ho, Ho & Lau, 2011). Hardware and software technological advances, which just three years prior was viewed as uncertain, immature and often cited as a reason not to implement RFID, had advanced to a point that global integration was a possibility.

However, limitations continued to be a lack of understanding on how to implement RFID (Li, Godon & Visich, 2010), a lack of organizational readiness and support, and the high implementation costs (Thiesse, Staake, Schmitt & Fleisch, 2011). Uncertainties and risks of global standardization, tag price and investment costs, security and privacy remained (Lee & Lee, 2011). ROI and net present value analysis at the company level were reported as critical to RFID acceptance (Lee & Lee, 2011). In 2011, as a sign of continued proliferation of the technology, ABI (2011) research estimated that nearly 750 million tags were used by the apparel and fashion retailers. As a continued sign of a ‘system’ view of RFID implementation, researchers reported a reduction in the bullwhip effect by improving inventory visibility and reducing safety stock levels (Zhou, Liu & Lin, 2010).

2012: Projections of a ‘Tipping Point’ for item-level tagging
In 2012, RFID was regarded as one of the most promising technologies (Attarin, 2012). A survey by the Voluntary Interindustry Commerce Solutions (VICS) Association conducted by Accenture
predicted that the retail industry was approaching the ‘tipping point’ for item-level tagging in retail (Gorshe, Rollman & Beverly, 2012). The report suggested that the tipping point was approaching as (1) item-level RFID could create a competitive advantage for early adopters, (2) that the technology had reached a point that it could drive improvements and inventory accuracy was ‘near perfect’, (3) that tag costs were falling, and (4) most major apparel and footwear retailers indicated that they would adopt the technology within the next 5 years (Gorshe et al., 2012). It appears that since the initial mandates several years earlier, innovative retailers quietly began item-level tagging soft-line merchandise in the U.S. (Gorshe et al., 2012). By 2012, major retailers, such as Macy’s, Bloomingdales and WalMart, neared completion of item-level RFID supply chain rollouts in many categories (Gorshe et al., 2012). However, most suppliers who participated in RFID tagging were responding to customer requests (Gorshe et al., 2012), and research reported that if compliance was the only purpose in RFID implementation, then there were no ROI advantages (Attarin, 2012). Managers reported that organizations planned or adopted RFID in operations in order to take advantage of efficient processes (Chen, Cheng & Huang, 2012).

The typical benefits noted improved inventory accuracy through elimination of transaction costs and real-time information for inventory management and control (Dai & Tseng, 2012; Xu, Jiang, Feng & Tian, 2012). With item-level RFID implementation, retailers reported a reduction in transportation costs and increased sales, better visibility into inventory, increased unit sales, and better full price sell-through, which all led to the ability to satisfy customer demand more effectively (Gorshe et al., 2012). At the same time, suppliers found benefits that were not anticipated: transportation cost savings and deeper insight into end customers (Gorshe et al., 2012). Other reported benefits included: enhanced customer and supply chain visibility, asset tracking improvements, smart product recycling, streamlined business processes, improved productivity and velocity, reliable and accurate forecasts, inventory cost reduction including stock-out and holding costs, improved ROI, improved accuracy due to reduction in human error, improved product quality, reliability and traceability, improved counterfeit identification, theft prediction and faster recalls, and enhanced long-term relationships with suppliers (Attarin, 2012). At the store level, RFID changed store operations as RFID was used to understand customer buying behaviors and shopping patterns and to improve the in-store shopping experience (Bertolini, Bottani, Ferretti, Montanari & Volpi, 2012; Hinkka, 2012), and a reduction in inventory levels, lead times stock out and shrinkage rates; direct insight into consumer buying habits and increasing efficiency and accuracy; customer service improvement; order accuracy; quality improvements; collaboration improvements, and the increased throughput, inventory visibility, and inventory record accuracy (Attaran, 2012).

The fundamental issues to RFID implementation include finding the ‘drivers’ for adoption, developing a positive ROI and the high capital costs (Attarin, 2012). Challenges include technology maturity, global standardization, government regulations and cost (Attarin, 2012). Internal challenges to adoption include high capital costs, ROI, lack of knowledge regarding RFID implementation, drivers and integration; while external challenges include security concerns, privacy and reliability, multiple standards, compatibility with existing IT systems, complexity, popularity of bar codes, government regulations and trust issues with partners (Attarin, 2012). Technology costs, change management and process re-engineering to gain the interoperability advantages promised through RFID integration in the supply chain were also
frequently cited barriers to implementation (Azevedo & Carvalho, 2012). In fashion supply chains, the main barrier to RFID deployment was interoperability (Azevedo & Carvalho, 2012). Influences on RFID adoption included: (1) clearly defined business needs/benefits; (2) top management involvement; (3) proper planning/scoping; (4) measurable business benefits (including ROI); (5) adequate funding; (6) competent technology partnerships; (7) integration of RFID into company’s existing IT architecture; (8) process incorporation into RFID implementation; (9) teamwork; and (10) staff training and participation in implementation (Attarin, 2012).

As a foreshadowing for what we are now seeing, in 2012, researchers predicted that the push for RFID would come from consumers pulling new or customized items from the supply chain as RFID has the potential to offer direct insight into consumer’s buying habits and demands as well as deliver on performance (Attarin, 2012). Researchers also predicted a change in the way that retailers operate to extend visibility through the supply chain and support sustainability efforts in end-of-life and recycling potential (Attarin, 2012). They also noted that cloud computing offers a potential solution to supply chain partners for global collection and data use (Azevedo & Carvalho, 2012).

2014: A Prediction of ‘Strong Growth’

By 2014, IDTechEx research indicated that the RFID market would grow to 9.2 billion, and that the world was entering a period of very strong RFID growth (MMH, 2014). Similarly, the GS1 Usage Standards Survey reported that on average 47% of apparel and general merchandise items delivered to retailers have tags, and 57% of retailers in the industry were implementing RFID (GS1US, 2016). Similarly, on average 40% of apparel and general merchandise manufacturers use RFID tags, and 48.2% of manufacturers were implementing RFID, while 29.8% of retailers and 39.5% of manufacturers in the apparel/general merchandise industry expected to implement RFID within the year (GS1US, 2016). Why did experts predict the ‘strong’ growth? As of 2014, researchers noted that omni-channel was the ‘way of the future’ for retailers and not just a trend (GS1, 2014). For example, Macy’s reported a 125% intended order on ‘buy online/pick-up in store’ efforts (GS1, 2014). Experts noted that the new paradigm was no longer B2B data exchange, but B2B2C as consumers sought accurate information regarding the product’s sourcing (GS1, 2014). By using RFID, users began to note the wealth and timeliness of information that could be used in advanced and intelligent replenishment strategies (Vlachos, 2014).

By 2014, benefits in other parts of the supply chain due to RFID use were noted. These included increasing inventory accuracy to 95% from 63%, expanding inventory count rates to 20,000+ an hour up from 200, reducing out-of-stock by up to 50%, increasing item availability to 20% from 2%, improving inventory labor productivity by 96%, and reducing cycle count time by 96% (GS1, 2014). Similarly, reported supply chain and logistics benefits included delivering an 80% improvement in shipping/picking accuracy, improving receiving accuracy, shrinking returns and claims, enabling electronic proof of delivery, reinforcing authenticity and anti-counterfeiting on luxury items, reducing loss prevention, and lowering receiving time by 90% (GS1, 2014). Knowledge of the system benefits for suppliers and retailers through shared, accurate, detailed information on inventory, supply and demand history existed, and with this information, Key Performance Indices (KPI’s) across the supply chain could be monitored, and more timely
decision-making could occur (Vlachos, 2014). At the warehouse level, supplier performance improvements were reported, which positively impacted upon the retailer’s inventory performance at its central warehouse (Vlachos, 2014). Additionally, retailers’ forecasting accuracy improved, which positively impacted upon order accuracy and replenishment (Vlachos, 2014). In other words, the system benefits and knowledge of these benefits were spreading through the supply chain.

2016: At the ‘tipping point’?
While retailers thought they had information systems in place that to adequately manage different inventory streams, during the holiday season of 2015, many retailers’ omni-channel distribution systems failed. It appears that many retailers are turning to EPC-enabled item level RFID as a solution to this problem. A 2016 Auburn University study reveals that RFID benefits extend upstream and downstream in a retail supply chain and inventory accuracy improves to 95% when retailers item track through to the stock location, inventory labor productivity improves by 96%, cycle counting time decreases by 98%, stock-outs are reduced by up to 50%, and item availability increases sales by 20% (Hardgrave & Patton, 2016). According to a recent Kurt Salmon survey of 60 European and US retailers and wholesalers the RFID adoption rate in the retail apparel, footwear and accessories doubled since 2014, up from 34% to 73% (Swedberg, 2016b). The survey points to the omni-channel growth and ROI for multiple channels (Swedberg, 2016b). While fewer than a dozen retailers in the US use RFID tags on items in stores, some retailers, such as Macy’s, believe that the retail industry has reached the ‘tipping point’ with respect to RFID implementation (Roberti, 2016b, 2016c). The reasons as to why industry watchers point to apparel as the first industry to adopt RFID tags on a large scale include the ability to read individual tags on a large scale, the wide variety of individual items that can be addressed, and some retailers (such as Marks & Spencer, Zara, and Kohl’s) already implemented RFID in inventory tracking (Roberti, 2016c). In fact, US retailers that adopted RFID increased 32% from June 2015 to June 2016, which is a significant increase over the prior year (25%) (Hardgrave & Patton, 2016; Roberti, 2016c). Additionally, the Auburn University RFID Lab study reports that 42% more apparel retailers (than the previous year) are launching proof of concept pilot studies at a limited number of stores for a limited number of merchandise categories (Hardgrave & Patten, 2016; Roberti, 2016c). Unfortunately, phased deployments only showed a small increase (18%), but the number of retailers with full deployments—tracking all items in all stores with RFID - doubled (Roberti, 2016c). A few recent RFID pilot studies are including RFID advanced capabilities – such as enhancing the customer experience and enabling key omni-channel capabilities – in their analysis (Hardgrave & Patton, 2016). *Omni-channel capabilities was not part of the conversation in 2006.* The Auburn University RFID lab highlights the fact that inventory accuracy is imperative for omni-channel distribution, and the 2015 holiday season highlighted the need for improving inventory accuracy to accommodate this (Hardgrave & Patton, 2016).

**Benefits and advantages to RFID Implementation Today:**
Growth over the past decade was severely limited by the great recession and patent enforcement agencies, but this appears to be changing as retailers’ launch pilots and phased deployment studies (Hardgrave & Patton, 2016). We continue the discussion by reviewing the key advantages and benefits to RFID in retail given today’s information systems capabilities and supply chain integration. These include, but are not limited to, bullwhip reduction, improved
inventory management, visibility and decision-making surrounding inventory movement in the supply chain and accuracy necessary to support omni-channel capabilities, and improved business processes.

RFID reduces the bullwhip effect through increased visibility regarding real-time information of items and location (Saygin et al., 2007) and improved information sharing between supply chain members (Zahaudin et al, 2006). Other researchers report improvement in supply chain performance through using RFID for inventory management and associated decisions, which improves coordination, increases inventory availability, saves labor and its costs, and reduces inventory levels (Sarac et al., 2010). Inventory management changes associated with RFID include order and replenishment processes, inventory levels and locations, safety stock levels and information sharing (Sarac et al., 2010). RFID improves inventory visibility and therefore reduces safety stock (Bottani & Rizzi, 2008), improves inventory replenishment (Wang et al, 2008), and improves forecasting accuracy (Imurgia, 2006). Information visibility using RFID item-level information in multiple periods improves decision-making (Zhou, 2009).

Key to retail supply chain implementation is to develop business cases that support it (Huber et al., 2007). Building a business case for the RFID has not been easy (Gorshe et al., 2012). In today’s fashion industry, RFID technology integration provides inter-organizational information sharing and improves the business processes that improves the entire supply chain (Pigni and Ravarini, 2008). Supply chain management process improvements include demand management (speed, accuracy and decision-making), order fulfillment (enhances visibility and information quality), manufacturing flow (asset tracking and process automation), reverse logistics (improves productivity, quality and reliability), and supplier relationship management (reduces operating costs and improved competitiveness) (Attarin, 2012). The most recent push for RFID implementation comes from the need for omni-channel distribution, which requires inventory accuracy (Hardgrave & Patton, 2016). Today, without EPC-enabled RFID, retailers may be unable to sell an item online and fulfill the order (GS1, 2014).

Limitations, Challenges and Barriers to RFID Implementation Today:
As noted above, a decade ago several obstacles limited RFID’s growth into the retail sector (Fish & Forrest, 2006). We continue by discussing the current status of these previously reported limitations, which today are not necessarily barriers that they once were.

Return on Investment (ROI): As we noted a decade ago, (Fish & Forrest, 2006; Fish & Forrest, 2007), critical to RFID reaching its ‘tipping point’ is the assessment of ROI beyond just the backroom. In the U.S. in 2006, retailers mandated that suppliers ship RFID-tagged case and pallet, which they met by the ‘slap-and-ship’ approach. We noted that in order for RFID to grow the integration between suppliers and customers needed to take advantage of the information for the benefit of both members. Others noted the same issue. For example, in 2008, researchers demonstrated that RFID and EPC adoption at the pallet-level provides benefits for all supply chain levels; however, it was not profitable for case-tagging for all members - particularly the manufacturer (Bottani and Rizzi, 2008). In 2010, for small-to-medium sized apparel retailers using RFID technology, the direct benefits were negative when considering direct fixed and variable costs of RFID implementation versus the manpower savings; however, if additional benefits, such as enhanced inventory accuracy, decreased time to market, and lead time reduction
to market, RFID application may be profitable (Wen et al., 2010). A decade ago, the supply chain echelon level impacted upon ROI, as manufacturers struggle to find a positive item-level tagging benefit (Gaukler & Seifert, 2007). As noted above, this is changing.

A positive ROI depends on technology costs, tag price, readers, middleware, implementation costs, and maintenance costs as well as other system implementation costs (Sarac et al., 2010). When a closed-loop supply chain exists and the tags can be reused, the tags costs are less important (Barbier & Lecoose, 2007). Traditional ROI focused on just the direct benefits, however, indirect non-financial benefits, such as reducing order fulfillment lead time and improved customer satisfaction, should be included as well (Leung et al., 2007). Accenture suggested a focus on increased sales as a method to evaluate ROI as item-level RFID pilots demonstrated that the technology reduces stock-outs and related missed sales opportunities (Gorshe et al., 2012).

Today, researchers report that ROI includes reduced time and labor costs, improved back-room to front-of-store inventory accuracy, self-checkout, out-of-stock, omni-channel fulfillment support and reduced shrinkage (Swedberg, 2016b). Reported gross margins increase by 5%, with the primary benefit as improved back-room to sale inventory accuracy and improved replenishment rates based upon that accuracy (Swedberg, 2016b). Following RFID adoption, key performance indicator improvements (in % improvement) include inventory accuracy (25.4% improvement), customer satisfaction (11%), store out-of-stock (40.6%), shrinkage (33.75%), profit margin (60.7%), and average markdown (19.6%) (Swedberg, 2016b).

**Tags & Technology:** A decade ago, Gen 2 RFID tags became the standard. These tags hold a variety of data, in a highly compact binary form, encoded in its memory banks. Tag costs varied over the decade, with reports indicating that they were as low as 7 to 15-cents apiece in 2009 (Kumar et al., 2009) and another report in 2012 indicating they were roughly a dime, depending upon the requirements and type (Gorshe et al., 2012). As RFID implementation continued and volume grew, researchers reported more expansive and less expensive tags using paper, plastic and ink (McGlaun, 2010), as well as active tags capable of transmitting signals up to 600 feet on the horizon (Attarin, 2012). RFID tags weigh roughly 50 grams, may be re-written up to 100,000 times, retain data without power for more than 10 years, and can be dropped from over a meter without harm (Kamal, 2013). As of 2014, the Auburn University Lab, GS1 US study noted that an EPC-enabled item level RFID is the key component to deliver end-to-end visibility (GS1, 2014). RFID implementation is feasible depending upon the product and environment (VanAssche, Weyn & Vercauteren, 2014).

In spite of decreasing costs and technology improvements since 2006, several issues remain. As recently as 2012, the overall tagging costs – the tag itself and labor to apply the tag - remain as one of the biggest obstacles to implementation (Gorshe et al., 2012). Other researchers report issues associated with assembling low-cost tags as well as imperfect read-rates (Attarin, 2012), and as recently as 2014, interference from metals and liquids remains a problem (VanAssche, Weyn & Vercauteren, 2014).

Since 2011, passive, Ultra-high Frequency (UHF) RFID systems improved significantly as the read range increased, and the antenna design and the sensitivity of the microchip improved
Technology: Technology over the past decade, while still changing and improving, has stabilized and matured. RFID readers use less power, operate faster at farther distances and handle interference better (Attarin, 2009). RFID middleware filters data from the readers to avoid information overload, ensure data accuracy, and feeds EPR systems with data to control and manage operations (Vlachos, 2014). Middleware issues existed in 2007 (Huber et al., 2007), and middleware uncertainty remained an issue in 2012 (Attarin, 2012). Readers and middleware are critical to an effective RFID implementation as data is exchanged through the supply chain system.

As of 2016, RFID systems need to capture the data more consistently as most overhead readers read only 50-90% of the tags as densely packed items block the reader (Roberti, 2016a). Interference caused by metals on apparel accessories and liquids remains an issue (Wen et al, 2010). Unfortunately, some passive RFID readers capture data of items that are not needed instead of ‘point’ specific data (Roberti, 2016a). There is a need to make the technology more ‘plug-and-play’ as today’s readers are a jumbled mess of wires and cables (Roberti, 2016a).

Security: Even by 2012, concerns about the potential for compromised data, data storage security and physical security of storage sites remained (Attarin, 2012). Viruses, hacking and tracking misuse existed (Kamal, 2013). Tracking misuse exists for spare parts and infringes upon third party production of comparable parts (Kamal, 2013). Cryptography producers are concerned about the ease with which personal data can be acquired from RFID tags, and the security flaws that exist in ‘security systems’ including the Texas Instruments Registration and Identification System (Kamal, 2013). Users of RFID may be short-sighted with roll-outs before security and privacy issues are fully addressed (Kamal, 2013).

Inditex SA, the parent of Zara, learned from JCPenney’s negative experience with RFID implementation, how to take advantage of item-level tagging and overcome consumer privacy issues (Bjork, 2014). J.C.Penney abandoned its original implementation when security tags conflicted with tag read rates and security tag removal lead to an increase in pilferage. Zara’s solution was to directly place the RFID tag into the security tag that is removed at checkout (Bjork, 2014). The solution reduces tag costs as the tag can be re-used and overcomes consumer privacy concerns as well (Bjork, 2014). European companies have lead item-level tagging around the world (Fish & Forrest, 2007). For example, since 2012, Gerry Weber, a German fashion retailer, weaves the RFID tag directly into its clothing care label for 20% of its stock (Gorshe et al., 2012). Today, RFID tag security features include preventing cloning and eavesdropping (Roberti, 2016a).

Standards and Privacy Issues: As recently as 2012, privacy concerns and differences in legislation around the world, as well as uncertainty surrounding the standards, remained (Attarin, 2012). Fortunately, standards issues continue to be addressed and there is some commonality
through the supply chain. GS1 Standards generate visibility, efficiency, safety and collaboration, and Electronic Product Code (EPC) allows for interactive applications between different forms using EPC Tag Data Standard 1.9. The GS1 System of Standards helps trading partners establish and maintain high quality, accurate data for item-level tracking. European Article Number (EAN) and UPC standards form part of the EPC standard (Huber et al., 2007). Electronic product code information services (EPCIS) is a standard way to capture, store and distribute data which originates in RFID systems (Kebo, Benes & Svub, 2012).

The key to extending RFID throughout the world lies within well-established security management practices and controls along with an appropriate legal framework (Kamal, 2013). Researchers reported that consumers’ acceptance will depend upon the technologies’ perceived usefulness (Muller-Seitz et al., 2009) as well as convenience, culture and security (Hossain and Prybutok, 2008). Many people still regard RFID as having significant individual privacy issues. Since RFID may be used to track an individual, many see it as an invasion of individual privacy - particularly if not regulated properly (Kamal, 2013). Individuals have no control over the RFID technology in their possession as the RFID presence may go undetected, global standards and policies vary, remote data capture may be automatic without the user’s knowledge, and it’s impossible to detect whether the tag remains active after the user acquires it (Kamal, 2013). Countries differ in their regulations, and as the world becomes more global, interpretation and implementation of these regulations become more difficult. As noted above, European companies have lead item-level tagging (Fish & Forrest, 2007), but with changing in tagging methods, U.S. retailers are increasing item-level tagging (GS1, 2014).

Civil liberty groups are concerned about the potential for linkages between the product databases and individuals, which may lead to unfair marketing practices (Kamal, 2013). Several global groups exist to advocate for individual privacy including: CASPIAN (Consumers Against Supermarket Privacy Invasion and Numbering), ACLU (American Civil Liberties Union), EPIC (Electronic Privacy Information Center), and OECD (Organization for Economic Cooperation and Development) (Kamal, 2013). The EPIC and Coalition of Privacy Organization’s recommend that merchants: be prohibited from forcing or coercing customers into accepting RFID tags, tags should be easily detected and disabled by individuals who possess the tag, should not track individuals through clothing, consumer goods or other items, and should not use RFID to reduce individual anonymity (Kamal, 2013). The OECD recommended guidelines to protect individual privacy include: openness and transparency through a right to know when products contain RFID tags or readers; required notice to the individual regarding the intended data collection purpose; and security and safeguards should be used (Kamal, 2013). Unfortunately, the OECD guidelines are not universally implemented as they are not obligatory.

As noted a decade ago, the laws governing RFID use vary throughout the world (Fish & Forrest, 2007), and today, they still vary. While the US Constitution does not express a specific right to privacy, judicial precedents exist which confirm the existence of privacy rights (Kamal, 2013). At the federal level, the U.S. legislature passed the REAL ID act that mandates the development of federal U.S. standards for driver’s licenses that could stimulate RFID deployment without preemptive measures (Kamal, 2013). In the U.S., states differ in their laws regarding RFID and individual privacy. California rejected a bill requiring retailers to remove the tags, but Utah passed a similar bill requiring retailers to inform consumers about the tags existence (Kamal,
2013). In Europe, the EU Data Protective Directive 1995 exists to ensure that data is processed fairly and lawfully, used only for specified, explicit and legitimate purpose and only kept as long as necessary (Fish & Forrest, 2007). In the EU, the personal data associated with RFID data must be used in compliance with prevailing legislation.

Factors influencing RFID Adoption Today
Reportedly, RFID item-level tagging in the retail sector is on the rise. What have we learned over the past decade?

1) RFID needed appropriate technology drivers – volume, cost reduction and need – to generate significant growth. As we outlined above and given the current retailer need to ‘know’ where an item is in real-time, RFID’s value to omni-channel distribution appears to be at the ‘tipping point’ necessary to drive full implementation in the industry.

2) Today’s managers have a better understanding of advantages, disadvantages and implementation than in 2007. The literature review above highlights the changing nature of implementation, benefits and limitations from a ‘local’ perspective towards a ‘system’ view. Today’s advantages and disadvantages speak to those found throughout the supply chain – and not just those for one member.

3) A broader system perspective between members exist today. Over the past decade, supply chains became more integrated, and the information requirements to achieve this have pushed for faster, more accurate information flowing between all members. Collaboration and integration are required to remain competitive in today’s market. RFID is moving from the ‘slap-and-ship’ manufacturing method that provided little information to the manufacturer but all the cost into manufacturing operations. Today, supply chain members – including manufacturing, distributors and retailers – value the information that RFID provides.

4) Over the past decade, the cost of implementation decreased due to the volume increase and the re-usability. In the U.S., many retailers adopted Zara’s security tag to RFID tag pairing, removing the tag at the point of sale. This method decreases the tag costs as they can be reused. By placing tags in security tag, retailers may have stumbled upon positive solution.

5) Similarly, by placing the RFID tag in the security tag, the consumer privacy issues in the United State are addressed. Since the tag remains on while the item is on the shop floor, the marketing benefits associated with ‘smart mirrors’ may be in the near future. However, by removing the tag at the point of sale, warrantee information still requires a paper-trail.

6) Over the past decade, middleware improved to filter information acquired through RFID. The volume of data posed a significant problem in the past; however, today’s information systems are poised to manage this through filters better than ever. Additionally, in 2005, Cloud computing was not available to the extent it is today. It has significant potential for sharing information in the future.
7) Given the research cited above, it is not surprising that retailers, who have the most to gain from item-level RFID, are pushing for implementation. Retailer key performance metrics, such as cost reduction and customer service, are improved through implementation. U.S. customers should look for ‘smart mirrors’ and ‘smart fitting rooms’ in the near future.

It is not surprising the IDTechEx reports that by 2020, the global RFID market is expected to reach $23.4 billion up from $6.98 billion in 2012 (Industrial Engineer, 2013). Similarly, the Auburn RFID lab study indicates that in the near future tagging will occur at the source, expanding RFID into category management, potential RFID reader solutions nearing implementation, and using the information for the entire supply chain and sharing data among all supply chain participants (Hardgrave & Patton, 2016). Continued proliferation will depend upon choosing the right technology (Angeles, 2005) and sharing implementation costs (Gaukler, Seifert & Hausman, 2007). Given current technology, sharing is more likely today than even 5 years ago. Information sharing and supply chain collaboration between members will decrease the uncertainties associated with end customer demand and increase the benefits from RFID implementation to all supply chain members (Sari, 2010).

Current limitations include treating RFID as a project instead of a foundational change, not properly analyzing and using the data, and improper analysis during the proof-of-concept or deployment phases as good comparison information is needed (Hardgrave & Patton, 2016). From a technology standpoint, the lack of in-house experts to implement RFID remained a problem as recently as 2012 (Attaran, 2012).

In today’s market, data provides the visibility to make better decisions, and RFID is one technology that can gather and disseminate that data in real-time. It appears that retailers have finally reached ‘the tipping point’ and consumers should be aware that RFID tags are coming to a store near you soon!

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A MULTI-OBJECTIVE DECISION MAKING MODEL FOR REMANUFACTURE-TO-ORDER SYSTEM

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ABSTRACT
This paper represents a Remanufacturing-To-Order (RTO) system, which receives End-Of-Life (EOL) products. It remanufactures, disassembles and recycles sensors embedded products (SEPs) to meet the quality-based products, components and materials demands respectively. A Linear Physical Programming (LPP) model is formulated in order to determine how the EOL products should be processed in order to meet the demands while minimizing the total cost and disposal weight and maximizing the quality level and material sales revenue.

INTRODUCTION AND RELATED WORK
SEPs can reduce or almost eliminate the uncertainties in planning of remanufacturing operations by providing item-based life cycle information. The sensors and radio frequency identification (RFID) tags help to collect information about missing, existing, types, conditions, and remaining lives of components in EOL products. Remaining useful life accounts for the quality of the EOL products. Managing EOL products consists of various recovery options, for example remanufacturing, refurbishing, repairing, component recovery and material recovery. Quality of collected EOL products is crucial in order to determine the best recovery option. Therefore, decision makers can construct sophisticated recovery models that guarantee a minimum quality level on recovered products based on the remaining lives while optimizing various system criteria.

Most real world decision-making and design problems are inherently multi-objective. One of the popular tools for multi-objective decision making is goal programming. Goal programming deals with the attainment of prearranged goals or targets. Goals fluctuate by numerical weights and can be characterized by a utility function. Many scientists feel that utility functions offer the perfect way to solve a multiple objective problem. But it is considered very difficult to achieve a mathematical representation of the decision maker’s (DM) true preference. On the other hand, a utility function has a major advantage in that if it is correctly evaluated and used, it will practically guarantee the most satisfactory solution to the DM.

One of the multi-objective decision making techniques, viz., Linear Physical Programming (LPP), has the ability to avoid the weight assignment by providing a preference function. Generally, optimization problem fit in one of two classifications viz.,
Blind and Physical optimization, where blind optimization situation happens when we wish to minimize (or maximize) a function subject to constraints, and we don’t have any knowledge about the physical meaning of the objective function or constrains, or the decision variable. On the other hand physical optimization takes place within the context of human beings making decisions that lead to the most satisfactory outcome. In LPP, DM determines a suitable preference function and specifies ranges of different degrees of desirability (ideal, desirable, tolerable, undesirable, highly undesirable, and unacceptable) for each criterion. There are eight preference functions classified into 8 classes, 4 soft and 4 hard. The soft classes are Class 1S (smaller-is-better, i.e., minimization), Class 2S (larger-is-better, i.e., maximization), Class 3S (value-is-better), Class 4S (range-is-better). The hard classes are Class 1H (must be smaller), Class 2H (must be larger), Class 3H (must be equal), and Class 4H (must be in range). Figure 1 illustrates the soft classes.

![Figure 1- LPP soft class functions](image)

Scholars have developed many real life application models using LPP. The preference functions in LPP are piecewise linear [2]. Kongar and Gupta [3], [4] developed an LPP model for solving a Disassembly-To-Order (DTO) problem. The model delivers the number of items to be disassembled for remanufacturing, recycling, storage and disposal. They studied nine criteria: average customer satisfaction, average quality achievement, resale revenue, recycling revenue, total profit and number of recycled items were defined as Class 2S type; average environmental damage and average environmental benefit were considered as Class 4S type; and the numbers of disposed items were defined as Class 1S type. Nukala and Gupta [5] developed an LPP model for the strategic and tactical planning of a closed loop supply chain. The model when solved detected concurrently the most economical used-product to re-process in the closed-loop supply chain, the efficient production facilities and
the right mix and quantity of goods to be transported across the supply chain. They implicated various cost criteria (viz., collection/retrieval cost, processing cost, transportation cost and disposal cost) as Class 1S while revenue criteria (viz., reuse revenue, recycle revenue and new product sale revenue) were modeled as Class 2S.

Ondemir and Gupta [6] determined the optimum disassembly, refurbishment, disposal, recycling and storage plans in a demand-driven environment by using LPP in sensor embedded products and RFID tags. Ondemir et al. [7], and Ondemir and Gupta [8] proposed a mathematical DTO model to fulfill demand for products with specific remaining life times, as well as components and materials by utilizing life cycle data using sensor information. Moreover, the authors presented an economic justification for establishing advanced DTO systems by extending the model in order to meet the complex product demands (Ondemir and Gupta, [9], Ondemir et al. [10]). Then, they considered an RTO system for EOL SEPs. An integer programming (IP) model was suggested to decide how to process an EOL product to meet products and components demands with respect of quality-based option and at the same time fulfill the minimum cost objective [11]. Ondemir and Gupta [12] introduced a multi-criteria Advanced Repair-To-Order and Disassembly-To-Order (ARTODTO) system for SEPs. The goal of their proposed system was to process an EOL product on hand to meet recovery products, components and recycled materials demands.

In this paper, we present an RTO system for EOL SEPs. In RTO system, RFID and sensor readers retrieve all the data stored in the EOL products. This data is then used to determine nonfunctional items and the remaining lives of all the functional items. Then based on their remaining lives (quality), EOL products are remanufactured to meet products demands, disassembled to meet components demands and recycled to meet materials demands. The LPP model determines how to process each and every end-of-life product on hand to meet the quality-based product and component demands as well as recycled material demand while minimizing the total cost, maximizing the quality level, maximizing the material sales revenue and minimize the disposal weight. The products are disassembled, remanufactured and recycled to meet the demands.

A case example is considered which represents a recovery facility that deals with 10 products to illustrate the proposed model. Each product consists of 6-10 components in various configurations. The recovery facility is equipped with RFID and sensor readers and determines the remaining lives of all components as soon as they arrive. Three quality level bins are assumed: bin 1, bin 2 and bin 3. Components with at least one year of remaining life are bin 1 quality components; components with at least three years of remaining life are bin 2 quality components, and components with at least five years of remaining life are bin 3 quality components. Components with less than 1 year of quality life are treated as nonfunctional and are used to fulfill material demands. The example is modeled using LPP and the results are obtained using LINGO 13.0 software.

REMANUFACTURING-TO-ORDER SYSTEM

A DTO system disassembles reusable parts and components to meet the component demands while the RTO system remanufactures, disassembles and recycles the EOL products to meet the products, components and materials demands. Outside procurement is considered to avoid back-orders. Disassembly can be destructive or non-destructive. Destructive disassembly is cost-effective but leaves the disassembled parts nonfunctional. All the data stored on EOL products is retrieved using sensor readers when they arrive at the product recovery facility. This data is then used to determine the remaining lives of the components.
Based on their remaining lives, they are divided into different quality level bins. During remanufacturing, nonfunctional, remaining life deficient and extra components are disassembled. Quality deficiency depends on the target quality level of remanufactured products. A low quality component is quality deficient when it is used to remanufacture a higher quality product and it needs to be replaced. Products have multiple configurations and hence few components may be exclusive to certain product configurations. Therefore, some functional components in EOL products may be extra depending on the target remanufactured product’s configuration.

**NOMENCLATURE**

**Variables**

- $x_i$: 1 if EOL product $i$ is disassembled nondestructively, zero otherwise
- $xd_i$: 1 if EOL product $i$ is disassembled destructively, zero otherwise
- $y_i$: 1 if EOL product $i$ is remanufactured, zero otherwise
- $x_{ijb}$: 1 if component $j$ of EOL product $i$ is disassembled and placed in bin $b$
- $y_{itm}$: 1 if EOL product $i$ is remanufactured to produce a product $t$ which will be evaluated as quality level $m$, zero otherwise
- $r_{jb}$: Number of operable components $j$ in remaining-life-bin $b$ that are recycled
- $rb_{j}$: Number of broken components $j$ that are recycled
- $rep_{itmjb}$: Takes the value 1 if a component $j$ from life-bin $b$ needs to be used to repair EOL product $i$ in order to make a product of type $t$ for life-bin $m$, zero otherwise
- $l_{jb}$: Number of components $j$ procured from outside in remaining-life-bin $b$

**Parameter**

- $b,i,j,k,m,t$: Running numbers
- $I$: Set of EOL products on hand
- $B$: Set of remaining-life-bins
- $J$: Set of components dealt with
- $M$: Alias for $B$
- $K$: Set of materials dealt with
- $T$: Set of product types dealt with
- $a_{ij}$: If EOL product $i$ is disassembled and contains an operable component $j$
- $f_{ij}$: Parameter taking value 1 if component $j$ is non-operable in an EOL product $i$
- $e_{ij}$: 1 if component $j$ is available and functional in EOL product, zero otherwise
- $c_{jb}$: Outside procurement cost of a component $j$, that would fit in component life-bin $b$
- $cd_{j}$: Disassembly cost of a component $j$
- $cr_{j}$: Recycling cost of a component $j$
- $cb$: Disassembly cost of a broken component
- $ca_{j}$: Assembly cost of a component $j$
- $dc_{jb}$: Demand for component $j$ in remaining-life-bin $b$
- $def_{itmj}$: Parameter taking the value 1 if component $j$ is remaining-life deficit in EOL product $i$ to make a product type $t$ for remaining-life-bin $m$, zero otherwise
- $dm_{k}$: Demand for material $k$
- $dp_{tm}$: Demand for product $t$ in remaining-life-bin $m$
- $ext_{ij}$: Parameter taking the value 1 if component $j$ is unnecessarily available in EOL product $i$ while making a product of type $t$, zero otherwise
- $mis_{ij}$: Parameter taking value 1 if component $j$ is missing in EOL product $i$ while making a product of type $t$, zero otherwise
FORMULATION

The objectives of the proposed RTO system are: minimizing the total cost, minimizing the disposal weight, maximizing the quality level and maximizing the material sales revenue. The system is formulated using LPP as follows:

Objective Function

The LP objective function is written as:

$$\min \phi = \sum_{u \in U, s \in \{2, 3, 4, 5\}} (\alpha_u^+ d_{us}^+ + \alpha_u^- d_{us}^-)$$  \hspace{1cm} (1)

Smaller—is—better (Class 1-S):

Total Cost \((TC)(g_1)\): Total cost is written as the sum of total disassembly cost \((TDC)\), total remanufacturing cost \((TRMC)\), total recycling cost \((TRC)\), and total outside procurement cost \((TOPC)\).

\[ g_1 = TC = TDC + TRMC + TRC + TOPC \]  \hspace{1cm} (2)

\[ TDC = \sum_{i \in I} [x_i \sum_{j \in J} ((1 - \epsilon_{ij}) * a_{ij}cd_j + f_{ij}cb) + xd_i cb \sum_{j \in J} (a_{ij} + \epsilon_{ij})] \]  \hspace{1cm} (3)

\[ TRMC = \sum_{i, j \in U} [y_{ij}cb(f_{ij} + \epsilon_{ij}) + cd_j \sum_{b \in B} rm_{ijb} + ca_j \sum_{t \in T, m \in M} y_{itm}(def_{itm} + mis_{itj})] \]  \hspace{1cm} (4)

\[ TRC = \sum_{j \in J} (rb_j + \sum_{b \in B} r_{jb}) \]  \hspace{1cm} (5)

\[ TOPC = \sum_{j \in J, b \in B} c_{jb}l_{jb} \]  \hspace{1cm} (6)

Disposal Weight \((DW)\) \((g_2)\): the disposal weight is given as:

\[ g_2 = DW = \sum_{j \in J} f_{ij} * (1 - p_{RC_j}) * w_j \]  \hspace{1cm} (7)

Class2-S: Larger-is—better

Quality level \((Q)\) \((g_3)\): The quality level is given as:

\[ g_3 = Q = \sum_{i \in I, j \in J, b \in B} a_{ij} (\beta - b) \]  \hspace{1cm} (8)

Material sales revenue \((MSR)\) \((g_4)\): The material sales revenue is given as:

\[ g_4 = MSR = \sum_{k \in K} prc_k (dm_k + sm_k) \]  \hspace{1cm} (9)

System Constraints:

All constraints of the system belong to hard classes.

\[ x_i + xd_j + y_j \leq 1 \hspace{1cm} \forall i \]  \hspace{1cm} (10)

\[ \sum_{b \in B} x_{ijb} = (1 - \epsilon_{ij})a_{ij}x_i \hspace{1cm} \forall i, j \]  \hspace{1cm} (11)

\[ \sum_{b \in B|cin_{ijb} = 0} x_{ijb} = 0 \hspace{1cm} \forall i, j, b \]  \hspace{1cm} (12)

\[ \sum_{t \in T, m \in M} y_{itm} = y_i \hspace{1cm} \forall i \]  \hspace{1cm} (13)
\[
\sum_{i \in I} y_{itm} = dp_{tm} \quad \forall t,m \\
\sum_{i \in I} \left[ d_{ij} x_{ijb} + \frac{rm_{ijb}}{\alpha} \sum_{t, m \in M} rep_{itmjb} + l_{jb} - r_{jb} \right] \quad \forall j,b
\]

where,

\[
\sum_{\{b \in B |cin_{ijb} = 0\}} rm_{ijb} = (1 - e_{ij}) \sum_{t, m \in M} y_{itm}(def_{itm} + ext_{it}) \quad \forall i, j
\]

\[
\sum_{\{b \in B |cin_{ijb} = 0\}} rm_{ijb} = 0 \quad \forall j, b
\]

\[
\sum_{\{b \in B |b \geq m\}} rep_{itmjb} = y_{itm}(mis_{it} + def_{it}) \quad \forall i, j, t, m
\]

\[
\sum_{\{b \in B |b < m\}} rep_{itmjb} = 0 \quad \forall i, j, t, m
\]

\[
\sum_{j \in J} (\gamma_{jk} (r_{jb} + \sum_{b \in B} r_{jb}) \geq dm_{k}) \quad \forall k
\]

\[
\alpha \sum_{i \in I} (f_{ij} + e_{ij})(\bar{x}_{ij} + \bar{y}_{ij}) \leq r_{jb} \leq \sum_{i \in I} (f_{ij} + e_{ij})(\bar{x}_{ij} + \bar{y}_{ij}) \quad \forall j
\]

**NUMERICAL EXAMPLE**

A product recovery facility receives sensors and RFID tags embedded EOL products. 10 different configurations of the products are available and each configuration deals with 6-10 components. The configurations of the products are given in Table 1. Table 2 displays some portion of incoming EOL products data. It provides information about EOL products, remaining lives and non-functional and missing components (NF means nonfunctional and "-" means missing components). The quality level of a component is defined by the remaining life of that component. All the information is captured by the sensors embedded in the products. Based on this remaining life, components are divided into three life-bins. The first life-bin holds components whose remaining life is at least one year. The second life-bin holds components whose remaining life is at least three years. The third life-bin holds components with remaining life of five years or more. The components with remaining life of less than one year are treated as nonfunctional.

**Table 1-Configurations of the Product types**

<table>
<thead>
<tr>
<th>Product types</th>
<th>Components</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>X X X X X X X X</td>
</tr>
<tr>
<td>2</td>
<td>X X X X X X X X</td>
</tr>
<tr>
<td>3</td>
<td>X X X X X X X X</td>
</tr>
<tr>
<td>4</td>
<td>X X X X X X X X</td>
</tr>
<tr>
<td>5</td>
<td>X X X X X X X X</td>
</tr>
<tr>
<td>6</td>
<td>X X X X X X X X</td>
</tr>
<tr>
<td>7</td>
<td>X X X X X X X X</td>
</tr>
<tr>
<td>8</td>
<td>X X X X X X X X</td>
</tr>
<tr>
<td>9</td>
<td>X X X X X X X X</td>
</tr>
<tr>
<td>10</td>
<td>X X X X X X X X</td>
</tr>
</tbody>
</table>
Table 2- Remaining lives of components

<table>
<thead>
<tr>
<th>EOL product</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>4.35</td>
<td>NF</td>
<td>5.05</td>
<td>3.45</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>3.29</td>
<td>3.11</td>
<td>5.96</td>
</tr>
<tr>
<td>2</td>
<td>4.67</td>
<td>2.86</td>
<td>-</td>
<td>5.03</td>
<td>1.31</td>
<td>6.57</td>
<td>NF</td>
<td>3.38</td>
<td>NF</td>
<td>6.58</td>
</tr>
<tr>
<td>3</td>
<td>3.03</td>
<td>4.30</td>
<td>2.63</td>
<td>7.58</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>NF</td>
<td>NF</td>
<td>NF</td>
</tr>
</tbody>
</table>

Table 3-Components Demands

<table>
<thead>
<tr>
<th>Component</th>
<th>Bin1</th>
<th>Bin2</th>
<th>Bin3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>20</td>
<td>22</td>
<td>17</td>
</tr>
<tr>
<td>2</td>
<td>16</td>
<td>12</td>
<td>15</td>
</tr>
<tr>
<td>3</td>
<td>22</td>
<td>22</td>
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<tr>
<td>4</td>
<td>31</td>
<td>20</td>
<td>14</td>
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<tr>
<td>5</td>
<td>15</td>
<td>31</td>
<td>16</td>
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<td>6</td>
<td>26</td>
<td>33</td>
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<tr>
<td>8</td>
<td>14</td>
<td>17</td>
<td>14</td>
</tr>
<tr>
<td>9</td>
<td>26</td>
<td>23</td>
<td>17</td>
</tr>
<tr>
<td>10</td>
<td>29</td>
<td>25</td>
<td>12</td>
</tr>
</tbody>
</table>

Components and products demands are shown in Table 3 and Table 4. Table 5 displays procurement, disassembly, recycling costs and material yields for all the components. Demands for materials A and B are 600 and 300 lbs. and destructive disassembly cost \( (cb) = $0.2 \) per component.

Table 4-Products Demands

<table>
<thead>
<tr>
<th>Product types</th>
<th>Bin1</th>
<th>Bin2</th>
<th>Bin3</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>6</td>
<td>4</td>
<td>8</td>
</tr>
<tr>
<td>2</td>
<td>6</td>
<td>4</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>12</td>
<td>10</td>
<td>8</td>
</tr>
<tr>
<td>4</td>
<td>12</td>
<td>2</td>
<td>8</td>
</tr>
<tr>
<td>5</td>
<td>10</td>
<td>0</td>
<td>6</td>
</tr>
<tr>
<td>6</td>
<td>2</td>
<td>6</td>
<td>8</td>
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<tr>
<td>7</td>
<td>10</td>
<td>8</td>
<td>10</td>
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<td>8</td>
<td>6</td>
<td>10</td>
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</tr>
<tr>
<td>9</td>
<td>6</td>
<td>6</td>
<td>8</td>
</tr>
<tr>
<td>10</td>
<td>4</td>
<td>10</td>
<td>8</td>
</tr>
</tbody>
</table>
Table 5-Procurement, disassembly, assembly, recycling costs and material yields

<table>
<thead>
<tr>
<th>Component</th>
<th>Procurement cost</th>
<th>Disassembly cost</th>
<th>Assembly cost</th>
<th>Recycling cost</th>
<th>Material A yield</th>
<th>Material B yield</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bin1</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1</td>
<td>20</td>
<td>40</td>
<td>50</td>
<td>1.5</td>
<td>1.5</td>
<td>0.1</td>
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<tr>
<td>2</td>
<td>40</td>
<td>30</td>
<td>60</td>
<td>1.5</td>
<td>1.5</td>
<td>0.1</td>
</tr>
<tr>
<td>3</td>
<td>60</td>
<td>70</td>
<td>75</td>
<td>1.5</td>
<td>1.5</td>
<td>0.1</td>
</tr>
<tr>
<td>4</td>
<td>15</td>
<td>20</td>
<td>25</td>
<td>0.5</td>
<td>0.5</td>
<td>0.1</td>
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<tr>
<td>5</td>
<td>15</td>
<td>20</td>
<td>25</td>
<td>0.5</td>
<td>0.5</td>
<td>0.1</td>
</tr>
<tr>
<td>6</td>
<td>15</td>
<td>20</td>
<td>25</td>
<td>0.5</td>
<td>0.5</td>
<td>0.1</td>
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<tr>
<td>7</td>
<td>12</td>
<td>18</td>
<td>24</td>
<td>2</td>
<td>2</td>
<td>0.2</td>
</tr>
<tr>
<td>8</td>
<td>18</td>
<td>22</td>
<td>26</td>
<td>2</td>
<td>2</td>
<td>0.2</td>
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<td>30</td>
<td>32</td>
<td>2</td>
<td>2</td>
<td>0.2</td>
</tr>
</tbody>
</table>

Table 6-Desirable ranges for each criterion

<table>
<thead>
<tr>
<th></th>
<th>Total Cost</th>
<th>Disposal Weight</th>
<th>Quality Level</th>
<th>Material Sales Revenue</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ideal</td>
<td>≤5900</td>
<td>≤0</td>
<td>≥1990</td>
<td>≥6500.00</td>
</tr>
<tr>
<td>Desirable</td>
<td>(5900.00,6200.00]</td>
<td>(0,21]</td>
<td>(1850,1990)</td>
<td>(5400.00,6500.00)</td>
</tr>
<tr>
<td>Tolerable</td>
<td>(6200.00,7100.00]</td>
<td>(21,35]</td>
<td>(1200,1850)</td>
<td>(4200.00,5500.00)</td>
</tr>
<tr>
<td>Undesirable</td>
<td>(7100.00,8000.00]</td>
<td>(35,49]</td>
<td>(700,1200)</td>
<td>(2900.00,4200.00)</td>
</tr>
<tr>
<td>Highly Undesirable</td>
<td>(8000.00,9500.00]</td>
<td>(49,65]</td>
<td>(0,700)</td>
<td>(2300.00,2900.00)</td>
</tr>
<tr>
<td>Unacceptable</td>
<td>&gt;9500.00</td>
<td>&gt;65</td>
<td>&lt;0</td>
<td>&lt;2300.00</td>
</tr>
</tbody>
</table>

Table 6 provides the desirable ranges for each criterion.

RESULTS

Linear physical programming weight (LPPW) algorithm was coded and run using MATLAB. Using the weights calculated, the mathematical model was constructed and solved using LINGO 13.0. Table 7 presents a sample of quality level bins in which disassembled components are placed and Table 8 presents some portion of details of product types and quality levels of EOL products. Table 9 illustrates the aspiration levels and values of all criteria. 170 EOL products were disassembled to meet the components demands, 15 EOL products were disassembled destructively to obtain parts for recycling, 200 EOL products were remanufactured to meet the products demands and rest were left untouched.
Table 7- Quality level bin in which disassembled components are placed

<table>
<thead>
<tr>
<th>EOL product</th>
<th>Components</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1 2 3 4 5 6 7 8 9 10</td>
</tr>
<tr>
<td>2</td>
<td>1 1 - 3 2 - - 2 1 3</td>
</tr>
<tr>
<td>.</td>
<td>. . . . . . . . . . .</td>
</tr>
<tr>
<td>.</td>
<td>. . . . . . . . . . .</td>
</tr>
<tr>
<td>398</td>
<td>1 1 2 - - - 3 3 2</td>
</tr>
<tr>
<td>400</td>
<td>2 2 3 1 - - 2 3 - 1</td>
</tr>
</tbody>
</table>

Table 8-Product types and quality levels of remanufactured EOL products

<table>
<thead>
<tr>
<th>EOL product</th>
<th>Product type</th>
<th>Quality level</th>
</tr>
</thead>
<tbody>
<tr>
<td>4</td>
<td>1</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>3</td>
<td>3</td>
</tr>
<tr>
<td>7</td>
<td>8</td>
<td>3</td>
</tr>
<tr>
<td>.</td>
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<tr>
<td>.</td>
<td>.</td>
<td>.</td>
</tr>
<tr>
<td>395</td>
<td>5</td>
<td>3</td>
</tr>
<tr>
<td>399</td>
<td>4</td>
<td>1</td>
</tr>
</tbody>
</table>

Table 9- Aspiration levels and values of criteria

<table>
<thead>
<tr>
<th>Description</th>
<th>Aspiration levels</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Cost</td>
<td>Desirable</td>
<td>6050.13</td>
</tr>
<tr>
<td>Disposal Weight</td>
<td>Highly Undesirable</td>
<td>51.71</td>
</tr>
<tr>
<td>Quality Level</td>
<td>Undesirable</td>
<td>903</td>
</tr>
<tr>
<td>Material Sales Revenue</td>
<td>Tolerable</td>
<td>4623.89</td>
</tr>
</tbody>
</table>

The total cost fell under “Desirable” range, disposal weight under “Highly Undesirable” range, quality level under “Undesirable” range and material sales revenue under “Tolerable” range.

CONCLUSION

Growth in production technologies is causing several environmental problems. This has given rise to Reverse Logistics (RL) and Environment Conscious Manufacturing and Product Recovery (ECMPRO). Uncertainty about the conditions and qualities of the returned EOL products complicates the product recovery planning. Use of sensors and RFID tags has helped in overcoming this issue.

In this paper, an RTO system was studied which receives sensor embedded EOL products. The life cycle information collected from sensor readers was used to determine the remaining lives of components from EOL products which is used to define the quality levels of the components. Using this information, an LPP model minimizing the total cost and disposal weight and maximizing the quality levels and material sales revenue was formulated. The model provides details about how each EOL product was processed in order to meet the components, products and materials demands. A numerical example was considered to illustrate the model’s application.
REFERENCES

A Paler Shade of Green: Implications of Green Product Deletion on the Supply Chain

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Abstract

Product management activities by marketing, operations, and finance functions have typically focused on the innovation, acquisition, growth, and management of product lines and products. The same is true when considering product management for green products. The latter stages of critical strategic decisions related to product deletion or discontinuation have received less emphasis. In this conceptual paper the focus is on the green product deletion implications for supply chain management, which some organizations may view as evolving from a deep green to a paler shade of green in their product offerings. A proposed strategic framework pays particular attention to implications for supply chain processes and operational competencies from the green product deletion decision. In this situation, lessened organizational greenness needs to be weighed against other organizational competencies. The strategic and inter-organizational relationships associated with this decision help set the stage for future research on this critical, yet neglected managerial and industrial marketing issue.

Keywords: Product deletion, green marketing, green product deletion, supply chain competencies, supply chain management
A theory on global supply chain design

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A global supply chain network consists of suppliers, production and service providers all performing different value-added activities to achieve value for consumers. In the realm of global supply chain strategy, networks are designed for responsiveness or efficiency; but typically not both. There is a wide range of literature on best practices, information sharing and integrated information technologies to support either strategy. This paper investigates the two contrasting global supply chain strategies and targeted KPIs (key performance indicators) associated with each strategy. This study then explores a complementary converging strategy for global supply chain design.
An Empirical Investigation of the Impact of Cross-Border Mergers and Acquisitions on Supply Chain

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Abstract

This study focuses on stock market reaction to the supply chain (acquirers and their major suppliers and customers) in the event of cross-border mergers and acquisitions (M&As) by US firms. The results show that cross-border M&As have a positive effect on US acquirers, and a negative impact on suppliers (upstream supply chain) and customers (downstream supply chain). The negative impact of M&As on supplier is stronger than customers. In addition, there exists a delayed response of stock market to suppliers and customers in the event of cross-border M&As.

We further explore the impact of firm’s strategy (industrial and global diversification) on the stock market reaction to supply chain using both event study method and regression analysis. We use the relatedness of acquirers/targets as measurement for industrial diversification, and the institutional infrastructure level of target country as proxy for global diversification. The results show that industrial diversification has no impact on the abnormal return in the supply chain and institutional infrastructure level of target country is negatively related to abnormal return of acquirers and suppliers.

Keywords: Cross-Border Mergers and Acquisitions, Industrial Diversification, Global Diversification, Supply Chain.

1. Introduction

The cross-border mergers and acquisitions (M&As) have experienced a tremendous increase in the last two decades. From 1998 to 2000, the total value of cross-border M&As was $4 trillion which is more than past 30 years (Henry, 2002). The number of cross-border M&As has increased at a 35% growth rate per year from 1985 to 2005, comparing to a 13% of domestic M&As (Mantecon, 2009).

For the cross-border M&As conducted by US firms, in about half deals, acquirers and targets are not in the same line of business. In addition, the deals on average involve 53 target countries each year (Table 1). Apparently more and more US firms use cross-border M&As for industrial diversification and global diversification. Nonetheless, the value of diversification has been long debated by academic researchers and practitioners.

On one hand, some studies find industrial and global diversification result in a large decline of acquiring firm value (Denis et al. 2002; Dos Santos et al, 2008) and a negative stock market reaction to acquirers (Moeller and Schlingemann, 2005; Freund et al, 2007). On the other hand, other studies shows industrial and global diversification enhances acquiring firm value (Errunza...
and Senbet, 1981; Kim and Lyn, 1984; Morck and Yeung, 1991) and is associated with a positive stock market reaction to acquirers. Some research argues the impact of industrial diversification on acquirers is different from that of global diversification. Bodnar et al. (1999) show industrial diversification reduces acquiring firm value while global diversification increases that.

It can be seen that majority of the exiting studies have focused on either acquirers or targets, or both. Few studies has examined the impact of M&As on the whole supply chain that includes the suppliers and customers of acquirers (Fee and Thomas, 2004; Kale and Shahrur, 2007; Hertzel et al., 2008; Raman and Shahrur, 2008; He et al., 2014). Fee and Thomas (2004) are the first to examine the stock market reaction to horizontal domestic merges and find insignificant abnormal return of suppliers and customers at the announcement date. Further, their analysis on the subsample supports the view that on average suppliers lose some form of buying power and customers do not benefit the cost savings from merging firms.

Extending previous research, this study focuses on the stock market reaction to the supply chain (US acquirers and their major suppliers and customers) in the event of cross-border M&As. We examine the market reaction to M&As by US firms acquiring non-US firms. We use the event-study method to calculate the abnormal return at four time period of (-1,+1), (-1, +5), (-10, +10), and (-15, +15), and we also analyze the impact of industrial and global diversification on the stock market returns using both event study method and regression analysis.

This results show that cross-border M&As have a negative abnormal return on suppliers and customers. The negative impact of M&As on supplier is stronger than customers. The acquirers have a positive abnormal return around the announcement date and is in consistent with the view that cross-border M&As increases acquirers’ value (Errunza and Senbet, 1981; Kim and Lyn, 1984; Morck and Yeung, 1991). Suppliers and customers have significant negative abnormal return around the announcement date, with the negative return increased from a shorter time window (-1, +15) to a longer time window (-15, +15). The results indicate that there exists a delayed response of stock market to suppliers and customers in the event of cross-border M&As.

Further, we explore the impact of industrial and global diversification on the abnormal return of acquirers, supplier and customers around the announcement day. We use the relatedness of acquirers/targets as measurement for industrial diversification, and institutional infrastructure level of target country as measurement for global diversification. We find no evidence that relatedness of the acquirers and target firms affect the abnormal return in the supply chain. Our results show that the market does not react to industrial diversification in cross-border M&As. We also find institutional infrastructure level of target country is negatively related to abnormal return of acquirers and suppliers. Because Unite States has a very high institutional infrastructure level, acquiring target in the countries with lower institutional infrastructure development by US firms represents more chance to arbitrate the world market imperfection and hence proxy a more global diversification. The fact that acquirers and suppliers of deals with the lower institutional infrastructure level of target country have higher abnormal return suggests global diversification brings more benefit than risk to acquirers and suppliers.

Our research contributes to the emerging supply chain finance research. Using a recent sample of cross-border M&As US firms, we are the first to identify the significant difference among the
market reaction to acquirers, suppliers and customers around the announcement date. Our research also makes contributions to the literature on the effects of global and industrial diversification. Our finding provides new evidence that market reaction to acquirers and suppliers in cross-border M&As is closely related to acquirers’ global diversification but not industrial diversification.

The remainder of this paper is organized as follows. In Section 2 we provide a literature review and develop the hypotheses. In Section 3 we discuss data and methodology. We present the results of our data analysis in Section 4. Conclusion and implications are provided in section 5.

2. Related Literature and Hypothesis Development

2.1 Industrial Diversification, Global Diversification, Firm Value and Stock Return

The existing studies examine the effect of international industrial and global diversification on both firm value and stock return. Some studies focus on the stock market return around the announcement of cross-border M&As and report a mixed result. Moeller and Schlingemann (2005) document a significant lower stock return for US firms acquiring foreign targets than those acquiring domestic targets. On contrast, Freund et al. (2007) test a sample of 194 US firms that acquired foreign companies during 1985-1998. They document a significantly positive stock market return in the announcement period for the acquirers. Both researches reveal the stock return is reduced by industrial and global diversification.

Some studies have focused on the relation between diversification and firm value and also find a mixed result. In terms of industrial diversification, Dos Santos et al. (2008) investigates the valuation effect of cross-border M&As of US acquirers over the period of 1990 to 2000. They use industry-matched multiplier approach to measure the firm’s excess value, and find industrial diversification from unrelated cross-border M&As results in a large decline of excess value, while they don’t find such result in related cross-border M&As. Their findings are different from the impact of domestic M&As. Graham (2002) reports a decline of firms’ excess value in both related and unrelated domestic M&As.

As for global diversification, Errunza and Senbet (1981) and Kim and Lyn (1984) find the international sales expand the business globally and increases the firm market value for US firms. Further, Errunza and Senbet (1984) show the direct foreign investment bypasses the market barrier and provide valuable international portfolio diversification services to investors, leading to a positive valuation effect on firm value. Morck and Yeung (1991) argue that the positive effect of internationalities on firms’ Q ratios does not stem from the portfolio diversification and however stem from research and development, and advertisement spending.

Bodnar et al. (1999) examine both industrial and global diversification using a sample between 1987 and 1993. They show operating in multiple industrial segments results in a lower firm value for multinational firms than domestic firms, while global diversification leads to a higher firm value comparing to similar domestic firms. On contrast, Denis et al. (2002) study a sample between 1984 and 1997 and show that both the global diversification and industrial diversification reduce firm value.
2.2 Mergers and Acquisitions Effect in the Supply Chain
An emerging line of finance research explores the impact of firms’ activity on their suppliers and customers’ operation performance (Kale and Shahrur, 2007; Hertzel et al., 2008; Raman and Shahrur, 2008; He et al., 2014). Fee and Thomas (2004) investigate the stock market return to the acquirers, suppliers, customers and rivals in horizontal domestic mergers. They find on average acquirers has a significant negative cumulative abnormal return for a three-day window centered on the merger announcement date. For suppliers, they document declines in cash-flow margins immediately subsequent to downstream mergers which stems from losing buying power in a long term. As for customers, Fee and Thomas (2004) find no evidence of significant cumulative abnormal return which supports their conjecture that customers do not benefit from the cost saving passed along by merging firms.

2.3 Hypothesis Development
This paper focuses on the stock market reaction to the supply chain in the event of cross-border M&As. It is proposed that impacts of cross-border M&As on acquirers, their suppliers and customers are different. In cross-border M&As, acquirers and targets may gain more power for monopolistic collusion. The consequence is that merging firms are more likely to coordinate an output reduction to seek for monopoly rents (Robinson, 1933; Eckbo, 1983, 1985; Eckbo and Wier, 1985). An output reduction leads to a lower input demand that affect suppliers negatively. The monopolistic collusion theory implies a negative stock reaction to suppliers.

Another theory is purchasing efficiency theory. Under the purchasing efficiency, the merging firms will share their resources to reduce the purchase cost from their suppliers, or use their increase bargain power from pool purchase to lower the purchasing price (Snyder, 1996; Brown et al., 2009; Hui et al, 2012). Purchasing efficiency theory implies a negative stock reaction to suppliers. Based on both theories, we suggest the following proposition:

\[ H1. \text{Stock return to suppliers in cross-border M&As is negative.} \]

In line of monopolistic collusion theory, merging firms gain more bargaining power from output reduction coordination and are likely to sell at higher price to customers. The implication is that market reaction to customers in cross-border M&As is likely to be negative. On contrast, in the view of purchasing efficiency theory, the saving from lower purchasing price or switching to more efficient suppliers by firms is possible to be passed along to customer (Fee and Thomas, 2004). Accordingly, cross-border M&As affect customers positively and the market reaction to customers is positive. These two competing theories lead to the following hypothesis in a null form.

\[ H2. \text{Stock return to customers in cross-border M&As is not significant.} \]
on suppliers in related cross-border M&As than in unrelated deals. This suggests the following proposition:

**H3. Stock returns of suppliers is lower in related M&As than in unrelated M&As.**

Similarly, acquiring firms in the related industry is more likely to form monopolistic collusion to gain more bargaining power on customers than that in unrelated cross-border M&As. The implication of monopolistic collusion theory is market reaction to customers in related deals is likely to be more negative than that in unrelated deals. In line of the monopolistic collusion theory, we suggest the following proposition:

**H4. Stock returns of customers is lower in related M&As than in unrelated M&As.**

In terms of global diversification, we consider one important target-country characteristic to evaluate its impact on the value of supply chain: the institutional infrastructure level. The value of a multinational network stems from the firm’s ability to arbitrage across institutional development level, and the operational flexibility from exploiting market conditions (Kogut, 1983; Aybar and Ficici, 2009). Because institutional infrastructure level of US is very high, acquiring targets in low institutional infrastructure development is a substantial strategy for US acquirers to take advantage of market imperfection. The global expansion of merging firms entails increase of demand to suppliers. Thus we postulate the following hypothesis.

**H5. Stock returns of suppliers in cross-border M&As with a low institutional infrastructure development target-country is higher than those with a high institutional infrastructure development target-country.**

The implication of acquiring firms’ global diversification to customers is different than to suppliers. Empirically, Birkinshaw et al. (2001) finds the evidence that as vendors move the relationship with their customers from country-by-country to a global one, the customers rely more on the vendors and bargaining power shift to vendors. As a result, customers experience a value reduction due to the reduced bargain power. As a measure of the extent of global diversification, the lower institutional infrastructure level of the targets, the more bargaining power losing by customers to acquirers. This suggests the following proposition:

**H6. Stock returns of customers in cross-border M&As with a low institutional infrastructure development target-country is lower than those with a high institutional infrastructure development target-country.**

3. **Data and Methodology**

3.1 **Sample Description**

This research focuses on the cross-border M&As by US acquiring firms. The Security Data Center (SDC) database from Thomson Reuters contains 16,462 cross-border M&As from January 01, 2000 to December 31, 2008. We include in our sample all deals that meet the following criteria: acquirer or acquirer’s parent firm is US firm; target or target’s parent firm is a foreign firm;
acquirer and target have data available in Compustat and CRSP. There are 6546 deals that met the sample formation criteria. Summary statistics for these deals are presented in Table 1.

Overall the deals have an increasing trend in the period of 2000 to 2008. We classified the deals as related deal if the acquirer and the target have the same two-digit SIC code and unrelated deal otherwise. There are 3421 related deals and 3125 unrelated deals in the sample. Table 1 also shows that top 20 target nations for cross-border M&As for the US acquiring firms. Top 5 target nations for cross-border M&As by US acquirers are United Kingdom, Canada, Germany, China, and France. The table also lists the Economic Freedom Index for the top 20 target countries. In 2008, the mean Economic Freedom Index for the top 20 target countries in cross-border M&As by US acquirers is 7.30 while the index is 8.06 for US.

3.2 Customers and Suppliers Identification
We identify the customers and the suppliers of the acquiring firms by using the segment data in COMPUSTAT. FASB No. 14 established standards of related disclosures for firms regarding reporting their customers with more than 10% of consolidated yearly sales, assets, or profit between 1977 and 1997. In June 1997, SFAS No. 131 extended the requirement beyond 1997. For example, Hertzel et al. (2008) studies the wealth effects of financial distress along the supply chain and Fee and Thomas (2004) investigated the sources of gains in horizontal mergers from the customers, suppliers and rivals.

The customer information in the COMPUSTAT is in an abbreviated format. The abbreviated format creates two difficulties in using the information. First, most of the name abbreviations don’t match the company names in either CRSP historical company name data or COMPUSTAT company name data. Second, different reporting companies may use the same name abbreviation to indicate different customers in their own reports. To correctly match the customer name with the company names in CRSP or COMPUSTAT, we closely follow the procedure developed by Fee and Thomas (2004) and go a few steps further. First, by comparing the letters and their orders in the abbreviation with those in the company names listed on CRSP or COMPUSTAT, we identified all qualified company names in which all the letters in the abbreviation are contained as well as appear in the same order. Second, different from the procedure by Fee and Thomas (2004) we check the reporting company’s filing to the SEC. In the SEC’s website, the filing can be tracked back as early as 1994 which contains the information in fiscal year 1993. Some filings reported the previous three years major customers so that the customer information can be obtained as early as 1991 from these reports. In the filing to the SEC, most of the reporting companies list their major customers’ full names and business segments. Third, for the customers without full name disclosure in the SEC filing, we use the available business description of the business in COMPUSTAT. We then eliminate the companies whose business has no logical relationship to the reporting company’s business. Fourth, for still uncertain abbreviations after going through the previous three steps, we check to see if its parent company is a listing company by means of its company’s website. If none of the previous procedures can build a clear link between the abbreviation and the company name, we follow Fee and Thomas’s (2004) conservative approach to not include these abbreviations in our analysis.

Following the above steps, we created a database with the companies and their customers. Then we were able to identify the suppliers by inverting the relationship in the COMPUSTAT database.
In total, we identified 3,436 suppliers in 991 cross-border M&As by US acquirers, and 570 customers in 397 cross-border M&As by US acquirers. On average, we identify 1.44 customer firms and 3.47 supplier firms for each cross-border M&A.

The firm characteristics of acquirers, suppliers, and customers are reported in Table 2. The mean market value of customers is 75,470 millions comparing to 14,067 millions for acquirers and 2,384 millions for suppliers. Among three groups, customers have the largest mean (median) asset, size, leverage, sales and net income, and suppliers the smallest asset, size, leverage, sales and net income.

### 3.3 Methodology

We use standard event-study method to compute the daily excess return to examine the stock market reaction to the announcement of cross-border M&As. Average daily abnormal returns (AR) are the measurement of the stock daily excess return. ARs are computed using standard event-study methodology following Brown and Warner (1985). First, we calculate the expected daily return using CAPM model. Each firm's alpha and beta coefficients are estimated from day -255 to day -46 respect to M&A announcement day. Second, we subtract the expected daily return from its actual return to get the abnormal return. The daily abnormal returns are summed to get the cumulative abnormal return (CAR) from day m prior to the M&A announcement day to day n after the M&A announcement day. We report our results from using the CRSP value-weighted indexes as market proxies. For each cross-border M&A, We form a portfolio of suppliers and customers respectively.

In deciding the length of the event window, past studies are inconclusive. Generally, it is suggested that an event window should be short enough to increase the power of the test and long enough to capture the full effect of the event (Uddin & Boateng, 2009). It is possible that it may take longer time for the market to react to suppliers and customers than to acquirers in a cross-border M&A. To capture short term and long-term impact of the M&As, this study uses a short event window ranging from one day before the announcement day to one day after the announcement day, and a relatively long event window ranging one day before the announcement day to fifteen days after the announcement day.

We use the relatedness to measure the industrial diversification. We classify the deal as an unrelated cross-border M&As if acquirer’ two-digit SIC code is not the same as target’s two-digit SIC code. Unrelated cross-border M&As is a strategy for industry diversification.

The valuation effects of a multinational network stem from the firm’s ability to arbitrage across institutional infrastructure development level, and the operational flexibility from exploiting market conditions (Kogut, 1983). Follow Aybar and Ficici (2009), we consider the level of institutional infrastructure development of target country as the proxy of global diversification. US has a very high institutional infrastructure development level each year. Acquiring firms in low institutional infrastructure development level is a substantial factor for US firms to take advantage of market imperfection.
In order to measure the institutional infrastructure level, we use an economic freedom index for each target country\(^1\). The index takes values between 1 and 10. Higher economic freedom index score indicates higher functional market economy. Target countries featured with low institutional infrastructure indicate a more global diversification for US firms.

We use cross-sectional regressions to further examine the relation between the stock-price reaction and diversification. We control for the method of payment for the cross-border M&As with the dummy CASH, which we set equal to one if the offer is made in cash. Travlos (1987) finds cash acquisitions have more positive stock market reaction than stock acquisitions because stock method is more likely to be used by overvalued firms. We expect a positive coefficient for the cash dummy. We also control for the relative size calculated by the acquirer’s size dividing by target’s size. Size of acquirers is positively related to the announcement return of acquirers in domestic M&As (Moeller et al., 2004).

4. Empirical Results

In this section, we report the overall announcement period returns during (-1, 1), (-1, +15), (-10, +10) and (-15, 15) around the cross-border M&As announcement for acquirers, suppliers and customers. We segment the results by related and unrelated deals as well as high institutional infrastructure development level target-country and low institutional infrastructure development level target-country. We then use the multivariable regression to examine the impact of unrelatedness and institutional infrastructure development level on the stock market reaction.

4.1 Abnormal Return for Acquirers, Suppliers and Customers in the Whole Sample

Panel A of Table 3 shows the announcement period stock returns in the whole sample. For acquirers, the mean CAR in three days window (-1, +1) is 0.49% and significantly different from zero at the 1% significant level. It shows the market perceives that cross-border M&As create value for acquirers. In the other window periods, the CAR is not significant.

For suppliers, the mean CAR is -1.27% in (-1, +15) window, -2.14% in (-10, +10) window and -2.71% in (-15, +15) window and are all statistically significant. The result shows suppliers are negatively affected by the cross-border M&As.

For customers, the mean CAR is -0.72% in (-1, +15) window and -1.35% in (-15, +15) window and are all statistically significant. The result shows customers are also negatively affected by the cross-border M&As. The negative CAR for suppliers and customers in cross-border M&As supports acquirers’ monopolistic collusion theory. The market reaction to customers in cross-border M&As is different domestic M&As in which acquirers do not squeeze the profit from customers (Fee and Thomas, 2004).

\(^1\) The index is accessible at https://www.fraserinstitute.org/studies/economic-freedom. The index is measured in five areas: size of government, legal structure and security of property rights, access to sound money, freedom to trade internationally, and regulation of credit, labor and business.
The mean CAR for the supply chain in cross-border M&As is shown in figure 1. It is interesting to notice the significant return to acquirers concentrates in a short period. On contrast, the significant return to suppliers and customers mainly takes place in a longer period window. This pattern shows there exists a delayed response of stock market to suppliers and customers in the event of cross-border M&As.

Panel D shows Kruskal–Wallis test for the mean CAR difference along the supply chain. The result shows the mean CAR among the acquirers, suppliers and customers are significantly different in all window periods. Overall, suppliers have the largest negative stock return, customers receive relatively smaller negative stock return and acquirers have marginally positive return.

4.2 Related vs. Unrelated
Next, to examine the relation between value creation and industrial diversification, we segment the sample into related deals and unrelated deals. The result is presented in Panel B of Table 3. The mean CAR in (-1, +1) for acquirers is 0.60% in unrelated deals and is 0.35% in related deals. Both are statistically significant. However, the difference of CAR is not significant (t=0.42). The result shows that industrial diversification through unrelated cross-border M&As are not perceived by market to create more value than related cross-border M&As. The result is consistent with the finding by Freud et al. (2007). As in the whole sample, the significant return for acquirers takes place in short window period (-1, +1) instead of other long window periods.

Panel B also shows the mean CAR for suppliers in related and unrelated deals. The mean CAR for suppliers in (-15, +15) period is −2.70% in related deals and is −2.72% in unrelated deals. The difference of CAR is no significant. The CAR in (-1, +15) and (-10, +10) period has the similar pattern. The result shows that market reaction to suppliers in related deals is the same as to suppliers in unrelated deals.

The mean CAR in (-15, +15) period for customers in both related deals and unrelated deals are insignificant. The difference of CAR is not significant. The finding shows that industrial diversification in cross-border M&As has no impact on stock return of customers.

Panel D shows Kruskal–Wallis test for the mean CAR difference along the supply chain in unrelated cross-border M&As and related cross-border M&As respectively. In both type of deals,
the result shows the mean CAR among the acquirers, suppliers and customers are significantly different in all window periods. Overall, on both unrelated deals and related deals, stock return to suppliers is the most negative, to customers is second negative and to acquirers is positive. The similarity of mean CAR in both types of deals indicates industrial diversification in cross-border M&As has no impact on stock return along supply chain.

4.3 High Institutional Infrastructure Level Target-Country vs. Low Institutional Infrastructure Level Target-Country

Further, to examine the relation between value creation and global diversification, we segment the sample into high institutional infrastructure level target-country deals and low institutional infrastructure level target-country deals. The result is reported in Panel C of Table 3. The mean CAR in three days window for acquirers in high institutional-infrastructure-development target-country deals is 0.33% and significant, while the mean return in three days window for acquirers in low institutional-infrastructure-development target country deals is 0.50% and significant. The results shows that M&As in which target country has low level of institutional infrastructure development (represent M&As with higher global diversification) received higher return than those in which target country has high level of institutional infrastructure (represent M&As with lower global diversification).

For suppliers, in Panel C, the mean CAR in (-15, +15) period in deals is -2.52% in low institutional infrastructure target-country subsample, while the mean CAR for suppliers in (-15, +15) period is -3.07% in high institutional infrastructure target-country subsample. The mean difference is also significant at 10% level. The CAR in (-1, +15) and (-10, +10) period has the similar result. The result shows the market perceives deals with low institutional infrastructure target-country affect suppliers negatively less than deals with high institutional infrastructure target-country. A plausible reason is the global diversification expands acquirers’ business and entails an increase of the demand to their suppliers. This positive effect partly offsets the negative the effect from the monopolistic collusion by acquirers.

For customers, in Panel C, the mean CAR in (-15, +15) period in high institutional infrastructure target-country subsample is -2.35% and that is insignificant for low institutional infrastructure target-country subsample. The mean difference is not significant. The result indicates that market reacts to the customers in cross-border M&As with low institutional infrastructure target-country the same as cross-border M&As with high institutional infrastructure target-country.

Panel D shows Kruskal–Wallis test for the mean CAR difference along the supply chain in high institutional infrastructure target-country M&As and low institutional infrastructure target-country M&As respectively. In both type of deals, the result shows the mean CAR among the acquirers, suppliers and customers are significantly different in all window periods. Average, acquirers receive the positive return and suppliers get the larger negative return than customers.

4.4 Regression Analysis of the Impact of Industrial and Global Diversification on the Stock Return

First, we examine the impact of industrial and global diversifications on the acquirers’ CAR with regression. The dependent variable is the mean CAR of acquirers around announcement period. The regression specifications are specified as follows:
\[ Acquirers’ \text{CAR} = \alpha_1 + \alpha_2 Unrelatedness + \alpha_3 \text{InfraDev} + \alpha_4 \text{Deal Variables} \] (1)

where \( Unrelatedness \) is a dummy variable that is set to 1 if the acquirer’s two digit SIC code is not the same as that of the target, 0 otherwise, \( \text{InfraDev} \) is the level of the target-country’s institutional development level and ranges from 1 to 10. We include two deal variables as the control variables: \( Cash \) is a dummy variable that equals to 1 if the deal is offered by cash, 0 otherwise; \( Size \) is the ratio of the acquirer’s size to the target’s size.

The result is reported in Table IV. In the first column, the dependent variable is acquirers’ CAR in (-1, +15). We include \( Unrelatedness \) and \( \text{InfraDev} \) in the regression. The coefficient of \( Unrelatedness \) is not significant and the result shows the industrial diversification does not affect the stock market reaction to acquirers. The coefficient of \( \text{InfraDev} \) is -0.004 and significant at 5% level. Because cross-border M&As with lower infrastructure level target-country means more global diversification for US acquirers, the result shows a positive impact of global diversification on stock return of acquirers. In the second column, we add \( Cash \) and \( Size \) into the regression. The coefficient of \( Unrelatedness \) is not significant while that of \( \text{InfraDev} \) is -0.005 and significant at 1% level. Both coefficients of \( Cash \) and \( Size \) are not significantly different from zero. In the third and fourth columns we use acquirers’ CAR in (-15, +15). The result is similar to that with CAR in (-1, +15).

Next, we examine the impact of industrial and global diversifications on the suppliers’ CAR with regression. The dependent variable is the mean CAR of suppliers around announcement period. The regression specifications are specified as follows:

\[ Suppliers’ \text{CAR} = \alpha_1 + \alpha_2 Unrelatedness + \alpha_3 \text{InfraDev} + \alpha_4 \text{Deal Variables} \] (2)

where independent variables are as defined in model (1).

The result is presented in Table VI. In the first column, the dependent variable is acquirers’ CAR in (-1, +15). We include \( Unrelatedness \) and \( \text{InfraDev} \) in the regression. The coefficient of \( Unrelatedness \) is not significant and the coefficient of \( \text{InfraDev} \) is -0.013 and significant at 5% level. In other words, the lower the institutional infrastructure level of target-country, the higher the stock return of acquirers, contrast to no significant impact from unrelatedness. In the second column, we add \( Cash \) and \( Size \) into the regression. The result remains the same as the first column. Both coefficients of \( Cash \) and \( Size \) are not significantly different from zero. In the third and fourth columns we use suppliers’ CAR in (-15, +15). The result is similar to that with CAR in (-1, +15).

Last, we examine the impact of relatedness and institutional infrastructure level of target-country on the customers’ CAR with regression. The dependant variable is the mean CAR of customers around announcement period. The regression specifications are specified as follows:

\[ Customers’ \text{CAR} = \alpha_1 + \alpha_2 Unrelatedness + \alpha_3 \text{InfraDev} + \alpha_4 \text{Deal Variables} \] (3)

where independent variables are as defined in model (1).
The result is reported in Table VI. In the first column, the dependent variable is customers’ CAR in (-1, +15). We include Unrelatedness and InfraDev in the regression. The coefficients of Unrelatedness and InfraDev are not significant. We then add Cash and Size into the regression in the second column. The coefficients of Unrelatedness and InfraDev remain insignificant. In the third and fourth columns we use customers’ CAR in (-15, +15). The result is similar to that with CAR in (-1, +15).

In sum, relatedness has no impact on the stock return to acquirers, suppliers and customers. The institutional infrastructure level of target-country is negatively related to the stock return to acquirers and suppliers, not customers.

5. Conclusion and Implication

In this paper, we examine the stock market reaction to US acquirers, their suppliers and customers in cross-border M&As. We found that suppliers have the largest negative stock return, followed by a smaller negative market stock return to customers, and a positive return to US acquirers. The result suggests that the increasing bargaining power for acquirers from the cross-border M&As has negative impact on suppliers and customers, which is in consistent with monopolistic collusion theory.

We further explore the impact of firm’s strategy (industrial and global diversification) on the stock market reaction to supply chain using both event study method and regression analysis. We use the relatedness of acquirers/targets as measurement for industrial diversification, and the institutional infrastructure level of target country as proxy for global diversification. The results show that industrial diversification has no impact on the abnormal return in the supply chain and institutional infrastructure level of target country is negatively related to abnormal return of acquirers and suppliers. In other words, the stock market does not react to industrial diversification but value the global diversification for acquirers and suppliers.

References


Table 1. Sample Description

The sample includes all cross-border mergers and acquisitions (M&As) between 2000 and 2008 that are covered in the Securities Data Corporation (SDC) database and that also meet the following criteria: acquirer or acquirer’s parent firm is a US firm; target or target’s parent firm is a foreign firm; acquirer and target have data available in Compustat and CRSP. When acquirers and targets have the same two-digit SIC code, the cross-border M&As is a related deal, otherwise it is an unrelated deal. Economic Freedom Index is the index in 2008.

Panel A: frequency by year and relatedness

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<th>Year</th>
<th>Deals</th>
<th>Target Countries Number</th>
<th>Related</th>
<th>Unrelated</th>
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<td>1126</td>
<td>70</td>
<td>563</td>
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<td>2001</td>
<td>724</td>
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<td>2008</td>
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Panel B: frequency by target country (top 20)

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<td>8.06</td>
</tr>
</tbody>
</table>
Table 2. Descriptive Statistics for US Acquirers and Foreign Targets

This table shows the means and median characteristics of acquirers, suppliers and customers. Size is the firm’s market capitalization. Leverage is measured as sum of long term debt and debt in current liability. The unit is in US$ millions. Our sample period is from January 2000 to December 2008.

<table>
<thead>
<tr>
<th></th>
<th>Acquirers</th>
<th>Suppliers</th>
<th>Customers</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>Median</td>
<td>Mean</td>
</tr>
<tr>
<td>Asset</td>
<td>24107</td>
<td>1219</td>
<td>1441</td>
</tr>
<tr>
<td>Size</td>
<td>14067</td>
<td>1664</td>
<td>2384</td>
</tr>
<tr>
<td>Leverage</td>
<td>8652</td>
<td>211</td>
<td>356</td>
</tr>
<tr>
<td>Sales</td>
<td>8106</td>
<td>981</td>
<td>1078</td>
</tr>
<tr>
<td>Net Income</td>
<td>594</td>
<td>49</td>
<td>36</td>
</tr>
<tr>
<td>Observations</td>
<td>4060</td>
<td>991</td>
<td>570</td>
</tr>
</tbody>
</table>
Table 3. Cumulative Abnormal Returns for Acquirers, Suppliers and Customers

This table provides the mean cumulative abnormal return (CAR) in period of (-1, +1), (-1, +15), (-10, +10) and (-15, +15) day of the cross-border M&A announcement for the sample. CAR is calculated using the market model where the parameters are estimated with CRSP value-weighted index over the period starting 255 days to 46 days prior to the announcement. CAR and the number of observations [N] are reported for the full sample and the following subsamples: related cross-border M&A group and unrelated cross-border M&A group; low institutional infrastructure development target-country group and high institutional infrastructure development target-country group. For each cross-border M&A, We form a portfolio of suppliers and customers respectively. The symbols $, *, ** denote statistical significance at the 0.10, 0.05 and 0.01 levels, respectively, using a generic two-tail test.

<table>
<thead>
<tr>
<th></th>
<th>Acquirer</th>
<th>Supplier</th>
<th>Customer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>CAR (%)</td>
<td>N</td>
<td>CAR (%)</td>
</tr>
<tr>
<td>Panel A</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>All Cross-Border M&amp;As</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(-1,+1)</td>
<td>0.49***</td>
<td>6955</td>
<td>-0.25</td>
</tr>
<tr>
<td>(-1,+15)</td>
<td>-0.13</td>
<td>6955</td>
<td>-1.27*</td>
</tr>
<tr>
<td>(-10, +10)</td>
<td>0.21</td>
<td>6955</td>
<td>-2.14***</td>
</tr>
<tr>
<td>(-15,+15)</td>
<td>-0.23</td>
<td>6955</td>
<td>-2.71***</td>
</tr>
<tr>
<td>Panel B</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Related Cross-Border M&amp;As</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(-1,+1)</td>
<td>0.35*</td>
<td>3440</td>
<td>-0.07</td>
</tr>
<tr>
<td>(-1,+15)</td>
<td>-0.47</td>
<td>3440</td>
<td>-0.79</td>
</tr>
<tr>
<td>(-10, +10)</td>
<td>-0.13</td>
<td>3440</td>
<td>-2.03**</td>
</tr>
<tr>
<td>(-15,+15)</td>
<td>-0.70</td>
<td>3440</td>
<td>-2.70*</td>
</tr>
<tr>
<td>Unrelated Cross-Border M&amp;As</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(-1,+1)</td>
<td>0.60***</td>
<td>3194</td>
<td>-0.44</td>
</tr>
<tr>
<td>(-1,+15)</td>
<td>0.09</td>
<td>3194</td>
<td>-1.78$</td>
</tr>
<tr>
<td>(-10, +10)</td>
<td>0.30</td>
<td>3194</td>
<td>-2.24**</td>
</tr>
<tr>
<td>(-15,+15)</td>
<td>0.09</td>
<td>3194</td>
<td>-2.72**</td>
</tr>
</tbody>
</table>
Panel C
High Infrastructure Level Target-Country M&As

<table>
<thead>
<tr>
<th></th>
<th>Chi-square statistic</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(-1,+1)</td>
<td>25.243</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>(-1,+15)</td>
<td>17.076</td>
<td>0.0002</td>
</tr>
<tr>
<td>(-10,+10)</td>
<td>23.382</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>(-15,+15)</td>
<td>16.977</td>
<td>&lt;0.0001</td>
</tr>
</tbody>
</table>

Low Infrastructure Level Target-Country M&As

<table>
<thead>
<tr>
<th></th>
<th>Chi-square statistic</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>(-1,+1)</td>
<td>15.4344</td>
<td>0.0004</td>
</tr>
<tr>
<td>(-1,+15)</td>
<td>10.403</td>
<td>0.006</td>
</tr>
<tr>
<td>(-10,+10)</td>
<td>10.595</td>
<td>0.005</td>
</tr>
<tr>
<td>(-15,+15)</td>
<td>5.802</td>
<td>0.054</td>
</tr>
</tbody>
</table>

Panel D Testing mean CAR differences among acquirers, suppliers and customers:
Kruskal–Wallis test

<table>
<thead>
<tr>
<th>Event Windows</th>
<th>Chi-square statistic</th>
<th>p-value</th>
</tr>
</thead>
<tbody>
<tr>
<td>All Cross-Border M&amp;As</td>
<td>25.243</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>(-1,+1)</td>
<td>17.076</td>
<td>0.0002</td>
</tr>
<tr>
<td>(-10,+10)</td>
<td>23.382</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>(-15,+15)</td>
<td>16.977</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>Related Cross-Border M&amp;As</td>
<td>15.4344</td>
<td>0.0004</td>
</tr>
<tr>
<td>(-1,+1)</td>
<td>10.403</td>
<td>0.006</td>
</tr>
<tr>
<td>(-10,+10)</td>
<td>10.595</td>
<td>0.005</td>
</tr>
<tr>
<td>(-15,+15)</td>
<td>5.802</td>
<td>0.054</td>
</tr>
<tr>
<td>Unrelated Cross-Border M&amp;As</td>
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<td>0.006</td>
</tr>
<tr>
<td></td>
<td>(-1,+15)</td>
<td>(-10,+10)</td>
</tr>
<tr>
<td>----------------</td>
<td>----------</td>
<td>-----------</td>
</tr>
<tr>
<td></td>
<td>12.592</td>
<td>15.249</td>
</tr>
<tr>
<td></td>
<td>0.002</td>
<td>0.001</td>
</tr>
<tr>
<td>High Infrastructure Level Target</td>
<td>Country M&amp;As</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-1,+1)</td>
<td>(-10,+10)</td>
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<tr>
<td></td>
<td>11.216</td>
<td>14.766</td>
</tr>
<tr>
<td></td>
<td>0.004</td>
<td>0.001</td>
</tr>
<tr>
<td>Low Infrastructure Level Target</td>
<td>Country M&amp;As</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-1,+1)</td>
<td>(-10,+10)</td>
</tr>
<tr>
<td></td>
<td>10.255</td>
<td>10.613</td>
</tr>
<tr>
<td></td>
<td>0.006</td>
<td>0.005</td>
</tr>
</tbody>
</table>
Table 4. Regression Analysis of Abnormal Return for Acquirers

This table presents the result for OLS regression model where the dependent variable is the cumulative abnormal return (CAR) of acquirers around the cross-border M&A announcement. The independent variables are measures for industry diversity (Unrelatedness), institutional infrastructure development (InfraDev). Unrelatedness is a dummy variable. The dummy variable Unrelatedness is 1 if acquirer and target have different two-digit SIC code and 0 otherwise. Cash is a dummy variable. The dummy variable Cash is 1 if offer payment method is cash and 0 otherwise. Size is the ratio of the acquirer’s size to the target’s size. Statistical significance of the regression coefficients is denoted with ***, **, or * for p-values less than one percent, five percent, and ten-percent respectively.

<table>
<thead>
<tr>
<th></th>
<th>CAR in (-1,+15)</th>
<th>CAR in (-1,+15)</th>
<th>CAR in (-15,+15)</th>
<th>CAR in (-15,+15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>0.026*</td>
<td>0.026*</td>
<td>0.028</td>
<td>0.028</td>
</tr>
<tr>
<td></td>
<td>(1.70)</td>
<td>(1.68)</td>
<td>(1.36)</td>
<td>(1.37)</td>
</tr>
<tr>
<td>Unrelatedness</td>
<td>0.002</td>
<td>0.002</td>
<td>0.006</td>
<td>0.006</td>
</tr>
<tr>
<td></td>
<td>(0.69)</td>
<td>(0.69)</td>
<td>(1.48)</td>
<td>(1.48)</td>
</tr>
<tr>
<td>InfraDev</td>
<td>-0.004**</td>
<td>-0.005***</td>
<td>-0.005*</td>
<td>-0.004*</td>
</tr>
<tr>
<td></td>
<td>(-1.99)</td>
<td>(-2.00)</td>
<td>(-1.73)</td>
<td>(-1.72)</td>
</tr>
<tr>
<td>Cash</td>
<td>0.001</td>
<td></td>
<td>-0.001</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.38)</td>
<td></td>
<td>(-0.09)</td>
<td></td>
</tr>
<tr>
<td>Size</td>
<td>0.003</td>
<td></td>
<td>0.003</td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.88)</td>
<td></td>
<td>(0.61)</td>
<td></td>
</tr>
<tr>
<td>R²</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
<td>0.001</td>
</tr>
<tr>
<td>Observations</td>
<td>6521</td>
<td>6521</td>
<td>6386</td>
<td>6386</td>
</tr>
</tbody>
</table>
Table 5. Regression Analysis of Abnormal Return for Suppliers

This table presents the result for OLS regression model where the dependent variable is the cumulative abnormal return (CAR) of acquirers’ suppliers around the cross-border M&A announcement. The independent variables are measures for industry diversity (Unrelatedness), institutional infrastructure development (InfraDev). Unrelatedness is a dummy variable. The dummy variable Unrelatedness is 1 if acquirer and target have different two-digit SIC code and 0 otherwise. Cash is a dummy variable. The dummy variable Cash is 1 if offer payment method is cash and 0 otherwise. Size is the ratio of the acquirer’s size to the target’s size. Statistical significance of the regression coefficients is denoted with ***, **, or * for p-values less than one percent, five percent, and ten-percent respectively.

<table>
<thead>
<tr>
<th></th>
<th>CAR in (-1,+15)</th>
<th>CAR in (-1,+15)</th>
<th>CAR in (-15,+15)</th>
<th>CAR in (-15,+15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>0.072</td>
<td>0.069</td>
<td>0.03</td>
<td>0.023</td>
</tr>
<tr>
<td></td>
<td>(1.54)</td>
<td>(1.47)</td>
<td>(0.48)</td>
<td>(0.36)</td>
</tr>
<tr>
<td>Unrelatedness</td>
<td>0.017</td>
<td>0.018</td>
<td>0.003</td>
<td>0.004</td>
</tr>
<tr>
<td></td>
<td>(1.60)</td>
<td>(1.63)</td>
<td>(0.24)</td>
<td>(0.30)</td>
</tr>
<tr>
<td>InfraDev</td>
<td>-0.013**</td>
<td>-0.013**</td>
<td>-0.005*</td>
<td>-0.005*</td>
</tr>
<tr>
<td></td>
<td>(-2.01)</td>
<td>(-2.01)</td>
<td>(-1.87)</td>
<td>(-1.87)</td>
</tr>
<tr>
<td>Cash</td>
<td>0.009</td>
<td>0.021</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(0.78)</td>
<td>(1.43)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Size</td>
<td>0.102</td>
<td>0.082</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.35)</td>
<td>(1.03)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R²</td>
<td>0.007</td>
<td>0.007</td>
<td>0.001</td>
<td>0.003</td>
</tr>
<tr>
<td>Observations</td>
<td>915</td>
<td>915</td>
<td>915</td>
<td>915</td>
</tr>
</tbody>
</table>
Table 6. Regression Analysis of Abnormal Return for Customers

This table presents the result for OLS regression model where the dependent variable is the cumulative abnormal return (CAR) of acquirers’ customers around the cross-border M&A announcement. The independent variables are measures for industry diversity (Unrelatedness), institutional infrastructure development (InfraDev). Unrelatedness is a dummy variable. The dummy variable Unrelatedness is 1 if acquirer and target have different two-digit SIC code and 0 otherwise. Cash is a dummy variable. The dummy variable Cash is 1 if offer payment method is cash and 0 otherwise. Size is the ratio of the acquirer’s size to the target’s size. Statistical significance of the regression coefficients is denoted with ***, **, or * for p-values less than one percent, five percent, and ten-percent respectively.

<table>
<thead>
<tr>
<th></th>
<th>CAR in (-1,+15)</th>
<th>CAR in (-1,+15)</th>
<th>CAR in (-15,+15)</th>
<th>CAR in (-15,+15)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Intercept</td>
<td>0.022</td>
<td>0.025</td>
<td>0.069</td>
<td>0.071</td>
</tr>
<tr>
<td></td>
<td>(0.56)</td>
<td>(0.63)</td>
<td>(1.35)</td>
<td>(1.36)</td>
</tr>
<tr>
<td>Unrelatedness</td>
<td>-0.006</td>
<td>-0.006</td>
<td>-0.011</td>
<td>-0.012</td>
</tr>
<tr>
<td></td>
<td>(-0.75)</td>
<td>(-0.81)</td>
<td>(-1.18)</td>
<td>(-1.19)</td>
</tr>
<tr>
<td>InfraDev</td>
<td>-0.003</td>
<td>-0.003</td>
<td>-0.010</td>
<td>-0.010</td>
</tr>
<tr>
<td></td>
<td>(-0.66)</td>
<td>(-0.63)</td>
<td>(-1.52)</td>
<td>(-1.51)</td>
</tr>
<tr>
<td>Cash</td>
<td>-0.011</td>
<td>-0.005</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(-1.52)</td>
<td>(-0.46)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Size</td>
<td>0.011</td>
<td>0.018</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>(1.23)</td>
<td>(0.78)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>R²</td>
<td>0.003</td>
<td>0.003</td>
<td>0.010</td>
<td>0.011</td>
</tr>
<tr>
<td>Observations</td>
<td>396</td>
<td>396</td>
<td>396</td>
<td>396</td>
</tr>
</tbody>
</table>
Big Data Analytics in Sustainable Logistics and Supply Chain Management: A Literature Review

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Abstract

The amount of the data produced by the government, the private sector and the general public has been rising especially over the past decade. With this growing trend, utilizing big data to add value to organizations became a popular topic for the industry and academic research. Converting unorganized and unstructured big data to useful information is investigated under Big Data Analytics (BDA). BDA, when employed appropriately, offers great potential to organizations helping in creating well-defined and meaningful strategic planning process. Supply chain Analytics (SCA) is a member of BDA with a narrower spectrum, concerned exclusively with supply chain and logistics operations. SCA utilizes various Big Data Analytics techniques such as future trend analysis and prediction and/or operational optimization to increase the overall performance of related activities. This study presents a literature survey in Supply Chain Analytics with a special focus on environmental and social sustainability.
Cost Sharing Warranty Policy Analysis for Remanufactured Product in Reverse Supply Chain

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Abstract
This paper presents an analysis of Non-renewing Cost Sharing Warranty (CSW) policy for an Advanced Repair-To-Order, Disassembly-To-Order and remanufacturing-To-Order system for Sensor-embedded products (SEPs). The goal of the proposed approach is to introduce the concept of providing a two-dimensional warranty policy for an end-of-life (EOL) product and how to predict a warranty period for the disassembled components using the sensor information about age and usage of each and every EOL product on hand to meet product, component and recycled material demands while minimizing the cost associated with warranty and maximizing remanufacturer’s profit.

Keywords: Reverse Supply Chain, Simulation, Non-Renewable Warranty Policies, Remanufacturing

INTRODUCTION

In current times, the exponential rise in technological development and the customers’ desire to repeatedly purchase newer device models and technological products is the impetus which culminates into diminished product life cycles and an upturn in their rate of disposal. As a result, landfill areas and the Earth’s natural resources start reaching a critical apex. Therefore, when a technological device reaches the end of its life and becomes essentially no longer usefull or just antiquated, manufacturing firms repossess these same products that they had produced prior, in order to manage to meet the new regulations imposed upon them and to enlighten customers’ awareness of the pertinent environmental issues regarding this matter. The manufacturers of these technological devices construct specialized facilities specifically designed for the end-of-life (EOL) product recovery process in order to minimize the amount of mechanical waste sent to landfills. This is achieved by retrieving the mechanical materials, parts, and components from the end-of-life products (EOLPs) by way of the recycling, refurbishing, and remanufacturing processes. The economic benefits from such facilities make the process of product recovery more attractive [1,2].
In product recovery, disassembly is the most vital operation because it allows for the extraction of the desired components, subassemblies and materials from EOL products. There are various ways to execute the process of disassembling EOL products. They can be effectuated at a single workstation, in a disassembly cell, or on a disassembly line. Although utilizing single workstations and disassembly cells are more flexible in nature, the operation that produces the highest yield is the disassembly line operation, which is also the most efficient operation for automated disassembly [3-6].

The quality of a remanufactured product induces hesitation for many people, in regards to its efficacy and reliability. Therefore, the consumers are unsure if remanufactured products will have the capacity to render the same expected performance as that of a new device. This uncertainty regarding a remanufactured product could lead the consumer to make a determination against its purchase. With such expansive consumer apprehension, remanufacturers often employ marketing strategies in attempts to provide affirmation about product durability. One stratagem that remanufacturers often employ to encourage customer security are product warranties [7,8].

A warranty is a contractual obligation incurred by a manufacturer (vendor/seller) in connection with the sale of a product. The purpose of a warranty is to establish liability in the rare event that a purchased item fails prematurely or is unable to perform its intended function. These contracts specify the promised product performance and when this expected performance level is not met, a return of compensation is available to the buyer as compensation [9,10]. Product warranties have different main functions. One of the functions is insurance and protection, permitting buyers to transfer the risk of product failure back to the sellers. Secondly, product warranties can also signal product reliability to customers [11,13], and lastly, the sellers can use warranties to extract additional profitability [14,15].

SYSTEM DESCRIPTION

The Advanced Repair-To-Order, Disassembly-To-Order, and remanufacturing-To-Order (ARTODTORTO) system deliberated in this study is a product recovery system. A sensor embedded air conditioner (AC) is considered here as an example product. Based on the condition of EOL AC, it will go through a series of recovery operations similar to the one shown in figure 1. Refurbishing and Repairing processes may require reusable components to meet the demand of the product. This requirement satisfies the internal and the external component demand. Both will be satisfied using disassembly of recovered components.

EOL ACs arrive at the ARTODTORTO system for information retrieval using radio frequency data reader that are stored in the facility’s database. Then the ACs go through a six-station disassembly line. Complete disassembly is performed to extract every single component. There are nine components in an AC consisting of, evaporator, control box, blower, air guide, motor, condenser, fan, protector, and compressor. Exponential distributions are used to generate the disassembly times at each station, interarrival times of each component’s demand, and interarrival times of EOL AC. All EOLPs after retrieval of the information are shipped either to station 1 for disassembly or, if EOLP needs only repair for a specific component, to the corresponding station. Two different types of disassembly operations, viz., destructive or
nondestructive, are used depending on the component’s condition. If the disassembled component is nonfunctional (broken, zero remaining life), then destructive disassembly is used such that the other components’ functionality will not be damaged. Therefore, unit disassembly cost for a functional component is higher than nonfunctional component. After disassembly, there is no need for component testing due to the availability of information on components’ conditions from sensors. It is assumed that the demands and life cycle information for EOLPs are known. It is also assumed that retrieval of information from sensors costs less than actual inspection and testing.

Recovery operations differ for each sensor embedded product (SEP) based on its condition and estimated remaining life. Recovered components are used to meet components and spare parts demands, while recovered or refurbished products are used for product demands. Also, material demands are met using recycled products and components. Recovered products and components are characterized based on their remaining lifetimes and are placed in different life-bins (e.g. one year, two years, etc.) waiting to be retrieved via a customer demand. Underutilization of any product or component could happen when it is qualified for a higher life-bin and is placed in a lower life bin because the higher life bin is full. Any product, component or material inventory that is greater than the maximum inventory allowed is assumed to be extra and is used for material demand or disposed of.

![Figure 1: ARTODTORTO System’s recovery processes](image)

In order to meet the product demand, repair and refurbish options could also be chosen. EOLP may have missing or nonfunctional (broken, zero remaining life) components that need to be replaced or replenished during the repairing or refurbishing process to meet certain remaining life requirement. EOLP may also consist of components having lesser remaining lives than desired, and for that reason might have to be replaced.
COST SHARING WARRANTY COST ANALYSIS

In the process of deciding to purchase merchandise, the buyers usually compare features of a product with other competing brands that are selling the same product. In some cases, the competing brands make similar products to each other with similar features such as cost, special characteristics, quality and credibility of the product and even insurance from the provider. In these cases, after sale factors come into effects such as discount, warranty, availability of parts, repairs, and other additional services. These factors will be very significant to the buyer in such situation and specially the warranty since it further assures the buyer of the reliability of the product.

A warranty is an agreement that requires the manufacturer to correct any product failures or compensate the buyer for any problems that occurs with the product during the warranty period in relevance to its sale. The objective of the warranty is to promote the products quality and guarantee its performance to assure production for both the manufacturer and the buyer.

Under this policy, the remanufacturer replace/repair failures of components if it is belonging to including set I at no cost to the buyer over the warranty period. Where if the failed components belong to the excluding set E, the cost of replacement/repair is carried by the buyer. The warranty agreement will specified which type of components or parts are in I or E set.

Here, the remanufactured components of the SEPs are grouped into two sets Included (I) and Excluded (E) components. Under CSW Policy, the set I corresponds to all the components which are covered by the warranty. Set E corresponds to all the components which are not covered by the warranty. Let \( N_I (RL; W) \) denote the number of failures over the warranty period which are covered and \( N_E (RL; W) \) denote the number of failures over the warranty period which are not covered under warranty for a SEPs.

NOMENCLATURE

The nomenclature used in this paper is given below:

- \( RL \): Remaining life
- \( W \): Length of warranty period
- \( Y \): Binary random variable associated with jth failure
- \( D_j \): Cost to remanufactured for replacement/repair jth failure
- \( B_j \): Cost to buyer for replacement/repair jth failure, \( j \geq 1 \) [Note: \( C_j = D_j + B_j \)]
- \( \bar{C}_b \): Expected cost to buyer per warranty claim
- \( \bar{C}_d \): Expected cost to remanufacturer per warranty claim
- \( Q \): Parameter for CSW Policy
- \( \Lambda \): Intensity function for system failure
- \( t \): Time at which warranty ceases
- \( E[C_d(W; RL)] \): Expected Total warranty cost to remanufacturer
- \( E[C_b(W; RL)] \): Expected Total warranty cost to buyer
- \( K \): independent simulation runs
\( S \): Set of all the components in an item

\( N_E(RL; W) \): Number of failures over the warranty period when failed remanufactured component \((s) \in E\)

\( N_d(RL; W) \): Number of failures over the warranty period when failed remanufactured component \((s) \in I\)

**PROBLEM FORMULATION**

In this policy, the failures are modelled as in Model S1 (Sensor Embedded, Corrective Maintenance) by a point process with intensity function \( \Lambda(rl) \). Still, with each point (corresponding to a failure) there is an indicator in the SEPs which specifies whether the remanufactured components failure is covered by warranty or not. This indicator could be modeled by a binary random variable \( Y \) with \( Y = 1 \) or \( 0 \) indicating that the failure is covered when \( Y = 1 \) or not covered under warranty when \( Y = 0 \).

Each failure of an item is marked whether the item failure is covered by warranty (Set Included) or not (Set Excluded). Let \( Y_{ji} \) be a binary random variable for the \( j^{th} \) failure with where \( i \) is the component which has failed. Then \( Y_{ji} \) is given by

\[
Y_{ji} = \begin{cases} 
1 & \text{for } i \in \text{Set } I \\ 
0 & \text{for } i \in \text{Set } E
\end{cases}
\]  

(1)

because the cost in this model is shared by the remanufacturer and the buyer, then,

\[
D_j = Y_{ji}C_j 
\]  

(2)

\[
B_j = (1 - Y_{ji})C_j 
\]  

(3)

Cost to the remanufacturer is given by

\[
E[C_d(W; RL)] = (\bar{c} - Q) + \int_{RL-W}^{RL} \Lambda(t) dt
\]  

(4)

Cost to the buyer, is given by

\[
E[C_b(W; RL)] = (\bar{c} - Q) + \int_{RL-W}^{RL} \Lambda(t) dt
\]  

(5)

**NUMERICAL EXAMPLE**

An AC with three different remaining lives (1 year, 2 years and 3 years) is sold with a CSW. It considers the warranty cost associated with the initial sale. The relevant cost elements are the cost of providing the repair. Cost models have been developed for the CSW rebate warranty by [16] and [17]. The models involve the costs and the distribution of time to failure assumes to be an exponential distribution. This assumption is proper when failures happen randomly during the warranty period at
a constant rate. To examine the effect of fluctuating the warranty period, it considered warranties length $W = 0.5, 1,$ and $2$ years.

Table 1: Operation costs (disassembly, assembly), sale price and repair cost for AC components

<table>
<thead>
<tr>
<th>Components</th>
<th>$Cs$ = Operation costs ($/unit)</th>
<th>$Cp$ = Sale Price ($/unit)</th>
<th>$Cr$ = Repair costs ($/unit)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>$L = 1$ Year</td>
<td>$L = 2$ Years</td>
<td>$L = 3$ Years</td>
</tr>
<tr>
<td>Evaporator</td>
<td>$4.00$</td>
<td>$10$</td>
<td>$15$</td>
</tr>
<tr>
<td>Control Box</td>
<td>$4.00$</td>
<td>$20$</td>
<td>$30$</td>
</tr>
<tr>
<td>Blower</td>
<td>$2.80$</td>
<td>$5$</td>
<td>$12$</td>
</tr>
<tr>
<td>Air Guide</td>
<td>$1.20$</td>
<td>$5$</td>
<td>$12$</td>
</tr>
<tr>
<td>Motor</td>
<td>$4.00$</td>
<td>$45$</td>
<td>$55$</td>
</tr>
<tr>
<td>Condenser</td>
<td>$1.66$</td>
<td>$15$</td>
<td>$18$</td>
</tr>
<tr>
<td>Fan</td>
<td>$2.34$</td>
<td>$15$</td>
<td>$18$</td>
</tr>
<tr>
<td>Protector</td>
<td>$0.60$</td>
<td>$15$</td>
<td>$20$</td>
</tr>
<tr>
<td>Compressor</td>
<td>$3.40$</td>
<td>$50$</td>
<td>$60$</td>
</tr>
<tr>
<td>AC</td>
<td>$55.00$</td>
<td>$180$</td>
<td>$240$</td>
</tr>
</tbody>
</table>

RESULTS

Table 2 presents the expected number of failures and cost for remanufactured AC and components for CSW, Policy. In Tables 2, the expected number of failures represents the expected number of failed items per unit of sale. In other words, it is the average number of warranty claims that the remanufacturer would have to provide during the warranty period per unit sold. Expected cost to the remanufacturer includes the cost of supplying the original item, $Cs$. Thus, the expected cost of warranty is calculated by subtracting $Cs$ from the expected cost to remanufacturer. For example, from Table 2, for $W = 0.5$ and $RL = 1$, the warranty cost for AC is $34.50 - Cs = 34.50 - 55.00 = 20.50$ which is $20.50 / 55.00 = 37.27\%$ saving of the cost of supplying the item, $Cs$, which is significantly less than that $55.00$, $Cs$. This cost might be acceptable, but the corresponding values for longer warranties are much higher. For example, for $W = 2$ years and $RL = 1$, the corresponding percentage is $42.30 - 55.00 = 23.09\%$.

As shown in Table 2 the expected warranty cost decreases with the remaining life of the remanufactured item, as to be expected. The results were determined by carrying out $k$ independent simulation run with $k = 2000$ for all simulation results. The mean and standard error of these $k$ independent runs is shown in Table 3. The confidence interval for the mean of $k$ independent simulations is given by

$$ C(k) \pm t_{k-1, (1-\alpha/2)} \sqrt{\frac{S^2(k)}{k}} $$

$\alpha = 0.05$

$$ \frac{S^2(k)}{k} = \sum (C_i - \bar{C}(k))^2 / (k - 1) \quad (7) $$

$$ 6 $$
Table 2 The expected warranty costs for CSW Policy

<table>
<thead>
<tr>
<th>Item</th>
<th>W</th>
<th>Expected Cost to Remanufacturer</th>
<th>Expected Cost to Buyer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RL 1</td>
<td>RL 2</td>
<td>RL 3</td>
</tr>
<tr>
<td>AC</td>
<td>0.50</td>
<td>$34.50</td>
<td>$33.10</td>
</tr>
<tr>
<td></td>
<td>1.00</td>
<td>$36.00</td>
<td>$36.39</td>
</tr>
<tr>
<td></td>
<td>2.00</td>
<td>$42.30</td>
<td>$41.67</td>
</tr>
</tbody>
</table>

For 1 year remaining life remanufactured AC sold with 0.5 year warranty, ARTODTORTO system can claim with 90% confidence that expected warranty cost of remanufacturer is in the interval [$34.38 - $36.62]. The confidence interval for a 1 year remaining life remanufactured AC sold with 2 years warranty is [$41.70 - $44.90]. For Buyer, For 1 year remaining life remanufactured AC sold with 0.5 year warranty [$22.88 - $25.12]. The confidence interval for a 1 year remaining life remanufactured AC sold with 2 years warranty is [$27.60 - $30.80].

Table Error! No text of specified style in document.3 Confidence Intervals for CSW Policy

<table>
<thead>
<tr>
<th>W</th>
<th>Confidence Interval on Expected Cost to Remanufacturer</th>
<th>Confidence Interval on Expected Cost to Buyer</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>RL 1</td>
<td>RL 2</td>
</tr>
<tr>
<td>0.5</td>
<td>L limit</td>
<td>U limit</td>
</tr>
<tr>
<td>1.0</td>
<td>$34.38</td>
<td>$36.62</td>
</tr>
<tr>
<td>2.0</td>
<td>$35.69</td>
<td>$38.31</td>
</tr>
</tbody>
</table>

CONCLUSION

The Cost Sharing warranty (CSW) policy cost for remanufactured products and components was evaluated in this paper for different periods and usages. The main objective was to introduce the idea of providing a two-dimensional warranty policy for an end-of-life (EOL) product and how to predict a warranty period for the disassembled components using the sensor information about the age and usage of each and every EOL product on hand to meet product, component and recycled material demands while minimizing the cost associated with warranty and maximizing manufacturer’s profit. A simulation model was used to optimize the system and predict the warranty period that should be assigned to each and every disassembled component and remanufactured product.

REFERENCES


ABSTRACT

The European Union Member States’ regulation and incentives for the electricity generated from renewable sources, though being bounded by the EU expectations and energy policies, produced a number of side-effects and an apparent regulatory deficit. We enumerate and identify those and suggest improvement possibilities for regulators.

KEYWORDS: energy strategy, renewables, supply chain risk
Abstract:

Additive Manufacturing (AM) technologies have been developed since the 1980s. They enable a physical object to be obtained from a 3D digital model in one-step manufacturing process. Limited for a long time to the production of prototypes, AM is now used to manufacture tooling and end-use parts, called also rapid manufacturing. Existing literature investigates economic and business AM models but it is still lacking an overall descriptive model for specific additive manufacturing supply chain for rapid manufacturing. Our paper aims at outlining the specificities of additive manufacturing supply chain. Based on review of prior works and through qualitative case study analysis of successful AM implementation in aerospace context, the paper proposes a descriptive design of additive manufacturing supply chain in the case of production of end-use parts at industrial scale. It also provides insights into the key points of the supply chain: the procurement of 3D Industrial printers, their spare-parts and raw materials and the production process including the post-processing. The paper highlights factors that are specific and have particular importance in the additive manufacturing supply chain due their unique characteristics and resource requirements.

Keywords: Additive Manufacturing Implementation, Supply Chain Management, End-use parts, Rapid Manufacturing, 3D Printing

1. Introduction

During the last decade, AM technology became mature and numerous companies are interested by implementing this new technology regarding to its advantages (Wohlers, 2012). AM technology is a set of seven processes (Rosenberg, 2015) which make it possible to manufacture a physical object by adding a material either layer upon layer, point by point or cord by cord from a 3D digital model. It is called additive as opposed to the conventional subtractive processes, as machining which operates by removing material. The AM offers great design freedom and very complex end-use parts are now feasible, within a very short time and with a lower manufacturing cost. Several works introduce the different AM processes and their fields of application (Gibson et al., 2015); (Groover, 2007) and (Hopkinson et al., 2006). Initially used for visual prototypes, the AM technology has now three main fields of application with a specific terminology: Rapid Prototyping or 3D Printing designates visual and functional prototyping, by rapid tooling the manufacture of tools and by direct manufacturing or rapid manufacturing the production of functional end-use parts. Rapid prototyping remains the main field of applications with 48% and only 19% for rapid manufacturing (Wohlers, 2012). The patents of two major processes expire: FDM\textsuperscript{1} in 2009 and SLS\textsuperscript{2} in 2014. As a result, prices for 3D printers drop significantly and technology is becoming available to small and medium-sized companies and also for home fabrication. While a lot of work has already investigated the implementation of AM for rapid prototyping, little has been done for direct manufacturing application. Given the growth in use for

\footnotesize{\textsuperscript{1} Fused Deposition Modeling \textsuperscript{2} Selective Laser Sintering}
additive manufacturing, a new field of research emerges with some works analyzing additive manufacturing by economic sight (Munguia et al., 2008); (Atzeni & Salmi, 2012); (Weller, et al., 2015) and (Mellor et al., 2014), societal sight (Huang et al., 2013) and (Rayna & Striukova, 2016) business models sight. There is little work by the supply chain sight. Research has been carried out for specific application as spare parts supply chain for small batches (Khajavi et al., 2014). Furthermore, the decisions on production and supply chain network design become increasingly important for the firm to obtain competitive advantage (Macchion, et al., 2015). The expectations for end-use parts are quite different from those for prototyping as production cycle, quality, reproducibility, etc.

The main contribution of our work is providing a descriptive design of additive manufacturing supply chain in the case of production of end-use parts at industrial scale. It also provides insights into the key points of the supply chain: the procurement of 3D Industrial printers, their spare-parts and raw materials and the production process including the post-processing. The paper highlights factors that are specific and have particular importance in the additive manufacturing supply chain due their unique characteristics and resource requirements.

In next section, an overview of AM technology is presented along with a brief theoretical background. Then the design of additive manufacturing supply chain is presented with a detailed constructs and supporting literature. The case study, based on successful implementation of additive manufacturing in aerospace sector, and the data collection process are described. Next, the results of this design are analyzed and discussed. Finally the paper ends with conclusions, limitations of our work and suggestions for future research.

2. An overview of Additive Manufacturing technology

The enthusiasm of manufacturers and makers for AM technology can be explained by the advantages it offers compared to conventional manufacturing process as turning. Different comparative investigations between conventional and additive methods have been conducted over the last twenty years. Some have been working on the subject since the beginning of prototyping such as (Holmström et al., 2010). The advantages of additive manufacturing are huge. The main ones are: rapid development of new products, customized parts, freedom in design, more complex parts, minimum use of material, more efficient supply chain with shorter lead times and with lower inventories. We discuss further the limitations of some advantages as shorter lead times and minimal use of material.

The term of “Additive Manufacturing” covers different technologies which differ according the material used (plastic, metal, etc.) and the energy source (laser, electron, etc.). The most used AM technologies are FDM® and SLS® (Wohlers, 2012). During the last decade, AM technologies growth rapidly and change significantly the production process and supply chain (Markillie, 2012) and (Schumpeter, 2012).
AM technologies differ from conventional manufacturing technologies by their following unique characteristics (Holmström et al., 2010): No tool is need; one-step manufacturing; small batches are profitable; optimized design due to topology optimization\(^3\).

The operational process of the additive manufacturing is operating (Gibson et al., 2015) into eight main steps: 3D Design and 3D Digital model conception, conversion to standard file (generally STL standards) compatible with the AM Machine, Transfer of standard file to AM Machine, AM Machine setup, build during this step AM machine is autonomous and works without external intervention, part removal and cleanup, post-processing and application. Some steps are critical during the production process as setup, part removal and post-processing. Limited variation in energy power (laser) of one or two watts can affect definitively the part quality.

Implementing AM technologies successfully requires some specific skills as: 3D Design, Master the different production steps (building and post-processing).

**Theoretical background**

Porter (1985) suggests that technology is perhaps the principal source of major market share changes among competitors. (Voss, 1988) provided huge researches on implementation by distinguishing it as distinctive field of research of process innovation. He defines the implementation as "the process that the user puts in place to ensure the success of the adoption of a new innovative technology". In the 1990s emerged the first research work on the implementation of additive manufacturing. A structural and normative model containing the key factors for successful AM implementation is proposed by (Mellor et al., 2014). It is based on five main factors which are: Strategy, Supply Chain, Operations, Organizational changes, AM technology. In order to contribute to this area of study, the paper focus on Supply Chain factor for end-used parts at industrial scale. The work of (Mellor et al., 2014) is developed on case study of AM Prototypes Company.

### 3. Additive Manufacturing Supply Chain Design

The model of Additive Manufacturing Supply Chain put forward by authors is illustrated in figure 1. The theoretical framework on the implementation of new technologies (Zmud, 1984); (Majchrzak, 1988); (Hattrup & Kozlowski, 1993) and (Noori, 1990) suggest the most relevant key players are: machine vendors, decision makers and production and maintenance staff.

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\(^3\) Topology optimization is a mechanical method during designing a part. It minimizes the material use but increases the resistance of part by optimizing the material deposite.
For direct manufacturing for end-use parts at industrial scale, we identify three supply chains:

- Raw material suppliers and AM manufacturers
- Machine Vendors and AM manufacturers
- Customers and AM manufacturers

The Additive Manufacturing Supply Chain can be organized as a process of five major linked nodes. These nodes are described in following sections:

3.1. Market demand

The AM customers can be classified in two categories:

- Novice customer without 3D design skills: Company has to design in 3D end-used parts according to the customer specifications. In fact, it has the entire responsibility of quality design
- Advanced customer with 3D design skills: the customer transfers read-to-print STL file and has the responsibility of 3D design. He became co-creator of product

Close interaction is needed between customer and manufacturer for deciding for AM technology, material type, expected quality, cost and delay.

3.2. Procurement management

We identify two procurement flows:

- Material procurement: the procurement reliability and quality of material is critical for AM technology at industrial scale. Furthermore, the material suppliers must ensure the traceability especially for metallic powder. The AM materials industry is not yet well organized for industrial scale use (Rosenberg, 2015) and (Wohlers, 2012).
3.3. Production management

Even if AM technology is known as one-step manufacturing process, the production node can be cut into two successive steps:

- Building starts by loading STL file until parts removal as shown in figure 1.
- Post-processing: specific treatments can then be carried out after building. It can be a simple dust removal for plastic parts or delicate chemical or heat treatments that have to be carried out in a very short time, less than 24 hours, after building under risk of deformation of the part. Specific ovens are needed for heat treatments. Final polishing treatment is carried out by subtractive technology, as machining, to obtain smooth surfaces.

3.4. Certification

Different quality control operations, as measurements, mechanical or chemical tests, can be carried out during certification final node. The tests and measurement must be done according ATSM AM standards policy and/or AM standards industry which can be higher than conventional standards.

3.5. Distribution

AM end-use parts are quickly shipped to the customers by small trucks. That ensures low delay.

4. Research methodology: data collection process

The selected company (X) case is a successful AM implementation for production of metal and plastic end-used parts. It has seven production locations over the world: five in Europe, one in U.S.A and one in Japan. It has high production flexibility and reactivity due its international implementation. Company X proposes a global offer for different industrial sectors: aerospace, armament, and nuclear. It has high skills in 3D design and obtained high certification AM technologies for aerospace industry. It uses FDM® & SLS® technologies for plastic and DMLS® technology for metal.

The data were collected in two steps:

- Interviews with Company CEO’s, production and maintenance staffs, 3D design engineer, production planner
- Visiting one manufacturing location in Europe focalized for aerospace industry and observing the supply chain process from 3D design until distribution

5. Results and Discussion

AM technologies allow reducing significantly material use that why aerospace industry was early interested in. AM end-used parts have a complex design and use 30% less material. This reduction is very advantageous, in particular for metal parts. Aircraft with AM parts consume less kerosene.
Company X uses titanium powder for metal parts. Titanium is widely used in the aerospace industry for its numerous qualities, in particular its resistance to fatigue. The average price of titanium is 40 €/kg. The buy-to-fly ratio measures the ratio between the mass of material used to make a part and the mass that actually flies. With conventional manufacturing such as machining, this ratio is on average 10% to 20%. The cost of material is then very high, as nearly 80% of the raw material is thrown. AM, on the other hand, is very competitive by offering a 100% buy-to-fly theoretical ratio and AM technologies for metal parts are economically more cost effective as demonstrated (Atzeni & Salmi, 2012). The titanium powder heated over several production cycles deteriorates, in terms of physicochemical characteristics, after a certain number of reuse and will no longer be compliant. This constraint can have an impact on the cost of production. Indeed, a large quantity of titanium powder can be discarded and thus reduce the buy-to-fly ratio of AM technologies.

The AM at industrial scale reveals several issues, including the supply chain of titanium powder: availability for high batches, dangerous explosive powder and potentially carcinogenic. Two suppliers for titanium powder, in U.S.A and in Canada, share 90% of the world market for titanium powder. The problem of availability and organization of supplies of these new materials is critical. Other issues are highlighted by the CEO about performances of 3D printers in industrial use. Indeed, 3D printer vendors come from the B to C and used to sell machines from 20 000 € to 40 000 € for prototyping.

**Conclusion and implications for future research**

AM technology offers numerous advantages as shown by (Holmström et al., 2010). However, designing a specific additive manufacturing supply chain seems important for successful AM implementation at industrial scale. This paper describes the different steps involved in the additive manufacturing supply chain. Some are critical as procurement of specific AM material and 3D printer spare parts, limited reuse of metallic powder over production cycles, 3D design and AM high standards.

Limitations of this paper include the fact that the proposed design for additive manufacturing supply chain was tested using a single case study. (Voss et al., 2002) suggests that single case research limits the generalisability of models and theory developed. However, this case study is a successful AM implementation in aerospace third-party industry for production of end-used metal parts at industrial scale.
References


ABSTRACT

Design for X is recognized as an important aspect in the management of End-Of-Life (EOL) products. Design for Disassembly (DfD) is a commonly researched topic along with Design for Recycling (DfR), Design for Remanufacturing (DfRem) and, Design for Environment (DfE). In this paper, an Advanced-Remanufacturing-To-Order-Disassembly-To-Order system is presented which evaluates design alternatives of sensors and RFID tags embedded EOL product types for ease of disassembly with other financial and environmental goals in order to fulfill products, components, and materials demands. The designs are evaluated based on the following four criteria: total profit, quality level, material sales revenue, and number of disposed items. The model is formulated and solved using the goal programming. An example of Air Conditioners is considered to illustrate the methodology.

INTRODUCTION

Electronic products are constantly updated with newer technologies and consumers are inclined towards buying the latest products even though their current product is in a good working condition. This has forced the products to reach their End-Of-Life (EOL) sooner. Therefore, even though a product is in good condition, its disposal is inevitable. In order to protect the environment from disposal of materials and accumulation of hazardous wastes, government has enforced strict rules and regulations on Original Equipment Manufacturers (OEMs). In order to comply with the rules and regulations, earn profits and protect the environment, OEMs are encouraged to implement various product recovery techniques such as reuse, recycling, and remanufacturing.

However, there are numerous uncertainties in the product recovery processes such as, the conditions of the received EOL products and the quantity and variety of EOL products that complicate the process [1]. To eliminate the uncertainties related to the conditions of the EOL product, sensors and Radio Frequency Identification (RFID) tags are embedded in the product [2]. RFID tags contain the static information about the product and sensors monitor the products’ use cycle and record its dynamic life cycle data [3]. This data enables the determination of remaining life of components [4]. Once the remaining life data is obtained, the optimal recovery decisions can be made without actual disassembly or inspection operations.
This paper considers an Advanced-Remanufacturing-To-Order-Disassembly-To-Order (ARTODTO) system which receives design alternatives of sensor embedded EOL products. Once the products arrive at the facility, the data captured by the sensors and RFID tags is gathered. This gathered data is used to evaluate the design alternatives of EOL products for the ease of disassembly of components and also to determine which of the EOL products should be remanufactured, disassembled, recycled and left untouched to meet the products, components, and materials demands. Though fulfilling the demands is the top priority, manufacturers also have to strategize a plan which not only fulfills the demands but also satisfies physical, financial and environmental goals. Therefore, this problem is considered as a multi-criteria decision making problem [5]. The designs are evaluated based on the following four criteria: total profit, quality level, material sales revenue, and number of disposed items. The model is formulated and solved using Goal Programming (GP). An example is considered to illustrate the methodology.

LITERATURE REVIEW

Environmental conscious manufacturing, product recovery, and disassembly have been the areas of interests of many researchers. Some of the relevant research related to the area of interest of this paper are reviewed here.

Disassembly is one of the most widely studied research area. Scholars have categorized the disassembly processes as: scheduling [6], sequencing [8], disassembly line balancing [9], disassembly-to-order [10], and automated disassembly [12].

Another important process is remanufacturing. It is an industrial process which converts the worn-out products into like-new conditions [13, 14]. Ilgin and Gupta [15] explained the details of remanufacturing in their book ‘Remanufacturing modeling and analysis’. Andrew-Munot et al. [16] examined the key motivating factors for companies to engage in remanufacturing program, and the major sources for acquiring used-products and subsequent markets for selling remanufactured products.

A lot of uncertainties exist in the processes of remanufacturing and disassembly. These uncertainties can be eliminated by embedding sensors into the products. Many research papers, literature reviews and books have been published on the use of sensors and RFID tags within the supply chain management area. For example, Blecker [17], Dolgui and Proth [18] and Sarac et al. [19] Fang et al. [20] examined use of sensor embedded products to facilitate remanufacturing.

These SEPs are available in various design alternatives. Evaluation of these alternatives in their design phase can help OEMs estimate the cost of their recovery. Aguiar et al. [21] proposed a diagnostic tool to evaluate product recyclability to be applied during the product design phase for designer decision making. The procedure allows to simulate the product redesign to improve its EOL performance. Cheung et al. [22] proposed and developed a roadmap to facilitate the prediction of disposal costs and to determine a solution of whether the EOL parts are viable to be remanufactured, refurbished, or recycled from an early stage of a design concept. Kim and Moon [23] introduced a design methodology to develop eco-modular product architecture and access its modularity for product recovery. They proposed a modularity assessment metrics to identify independent interactions between modules and the degrees of similarity within each module.

ADVANCED-REMANUFACTURING-TO-ORDER-DISASSEMBLY-TO-ORDER SYSTEM

This paper deals with an ARTODTO system which receives sensors embedded EOL products. Once the EOL products are received, all the data captured by the sensors is stored in a database. The extra information such as remaining lives of components is determined by means of this life cycle data and data retrieval mechanisms. Based on the remaining lives of components,
they are divided into different bins known as life bins. For example, life bin 1 may contain components of remaining lives of at least one year, life bin 2 may contain components of remaining lives between one and three years and life bin 3 may contain components of remaining lives of at least three years. Based on the remaining lives of components, the ARTODTO system remanufactures the products to meet the products demands, disassembles the components to meet the components demands and recycles the materials to meet the materials demands. The ARTODTO system is illustrated in Figure 1.

The ARTODTO system receives EOL products with design alternatives. Design alternatives are made available to customers to customize their demands according to their preferred manufacturer, model, version, use etc. All the design alternatives have the same function, and they share the same components but the specifications and arrangement of these components can be different in the alternatives. For example, split AC, packaged AC, windows AC and central AC are all design alternatives of an air conditioner. Evaluation of these design alternatives becomes crucial for selecting the optimum alternative. The various factors that may differ depending on the design alternative are, size and shape of the product, location of use, ease of disassembly, time for disassembly, and labor skills and costs.

To account for these factors, a disassembly factor is introduced which is defined as follows:

\[
f = \frac{\text{number of assemblies to disassemble}}{\text{total number of assemblies}}
\]

An assembly will be disassembled if it contains one or more target components or if it contains lower level assemblies that contain target components [22].

**NOMENCLATURE**

<table>
<thead>
<tr>
<th>Variable/Parameter</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>( MV )</td>
<td>Material value ($);</td>
</tr>
<tr>
<td>( Q )</td>
<td>Quality level;</td>
</tr>
<tr>
<td>( QDIS )</td>
<td>Total number of components disposed of;</td>
</tr>
<tr>
<td>( SCV )</td>
<td>Stored component value ($);</td>
</tr>
<tr>
<td>( SMV )</td>
<td>Stored material value ($);</td>
</tr>
<tr>
<td>( SPV )</td>
<td>Stored product value ($);</td>
</tr>
</tbody>
</table>
TP  Total profit ($);
TDC  Total disassembly cost ($);
TDISPC  Total disposal cost ($);
THOLC  Total holding cost ($);
TOPC  Total outside procurement cost ($);
TRECC  Total recycling cost ($);
TREMC  Total remanufacturing cost ($);
a_{ij}  1 if component j of EOL product i is functional;
B  Set of remaining-life-bins (for components);
b, i, j, k, m, t  Running numbers;
B_j  1 if component j is reused;
ca_j  Assembly cost of component j ($);
cde_j  Disposal cost of a component j ($);
chc_j  Holding cost of a component j ($);
C_j  1 if component j is recycled;
crc_j  Recycling cost of component j ($);
dc_{jb}  Demand for component j in remaining-life-bin b;
def_{ijb}  1 if components j in EOL product i is disassembled because of remaining life deficiency and placed in remaining-life-bin b during remanufacturing, zero otherwise;
dfc_{mj}  1 if component j of EOL product i is remaining-life-deficient for life bin m;
df_{ij}  Disassembly factor of component j in design alternative t;
D_j  1 if component j is stored;
dm_k  Demand for material k (lbs);
dpt_{tm}  Demand for design alternative t in remaining-life-bin m;
dtdd_j  Disassembly time for destructive disassembly of component j (hr);
dtndd_j  Disassembly time for non-destructive disassembly of component j (hr);
E_j  1 if component j is disposed of;
fd_j  Number of non-functional components js that are disposed of;
f_{ij}  1 if component j in EOL product i is non-functional;
fr_j  Number of non-functional components js that are recycled;
I  Set of EOL products on hand;
J  Set of components dealt with;
K  Set of material types dealt with;
lcdd_j  Labor cost for destructive disassembly of component j ($/hr);
lcndd_j  Labor cost for non-destructive disassembly of component j ($/hr);
l_{jb}  Number of components js purchased for remaining-life-bin b;
M  Alias for B (for products);
mhc_k  Holding cost for material k ($);
mis_{ij}  Binary parameter taking 1 if component j is missing in EOL product i, zero otherwise;
mv_k  Value of material k ($);
opcj_b  Outside procurement cost of a component j for life-bin b ($);
phc_i  Holding cost of product i ($);
rep_{mj}  1 if a component j from life-bin b needs to be used to remanufacture EOL product i in order to make a product for life-bin m, zero otherwise;
r_{jb}  Number of components js in remaining-life-bin b that are recycled;
rp_{ij}  1 if component j in EOL product i is disassembled during remanufacturing, zero otherwise;
rv_j  Resale value of component j ($);
s_{cj}  Number of components js in remaining-life-bin b that are stored;
sm_k Amount of material k stored (lbs);
spv_i Stored value of product i ($);
V_i 1 if EOL product i is remanufactured;
W_i 1 if EOL product i is disassembled;
X_i 1 if EOL product i is recycled;
x_{ijb} 1 if component j in EOL product i is disassembled and placed in remaining-life-bin b, zero otherwise;
Y_i 1 if product i is stored, zero otherwise;
y_{im} 1 if EOL product i is remanufactured to make a product for remaining-life-bin m;
Z_i 1 if EOL product i is disposed of;
\beta_{ij} The highest life-bin that component j of EOL product i can be placed in;

PROBLEM FORMULATION

In GP, criteria are referred as goals. Four goals considered in this formulation in the order of priorities are total profit, number of disposed items, material value and quality level.

The first goal of the system is to maximize the total profit. The aspiration level is set at TP*. It is expressed as follows:

\[ TP + \eta_1 - \rho_1 = TP^* \] (2)

The second goal of the system is to maximize the quality level. The aspiration level is set at Q*. The mathematical expression is written as follows:

\[ Q + \eta_2 - \rho_2 = Q^* \] (3)

The third goal of the system is to minimize the number of disposed items. The aspiration level is set at QDIS*. It is expressed as follows:

\[ QDIS + \eta_3 - \rho_3 = QDIS^* \] (4)

The fourth goal is to maximize the material value. The aspiration level is set at MV*. The mathematical expression is written as follows:

\[ MV + \eta_4 - \rho_4 = MV^* \] (5)

Total Profit is the subtraction of costs from the revenues. It consists of resale revenue, stored material value, stored product value, stored component value, total disassembly cost, total remanufacturing cost, total recycling cost, total outside procurement cost, total holding cost, and total disposal cost. The total profit function can be written as follows:

\[ TP = RSR + SMV + SPV + SCV - TDC - TRMC - TRCC - TOPC - THC - TDIC \] (6)

\[ RSR = \sum_{j \in J} B_{jrv} \] (7)

\[ SMV = \sum_{k \in K} sm_k * mv_k \] (8)

\[ SPV = \sum_{i \in I} Y_i * spv_i \] (9)
Number of disposed items (QDIS) is mathematically expressed as follows:

\[ QDIS = g_2 = \sum_{j \in J} (\sum_{i \in I} a_{ij} + f_{ij}) + \sum_{b \in B} f_{db} \]  

Material value (MV) is mathematically expressed as follows:

\[ MV = g_3 = \sum_{k \in K} mv_k (dm_k + sm_k) \]  

Quality level (Q) is defined as the difference between the highest life bin a component can be placed in, and the life bin it is actually placed in. It is divided into two terms, \( Q^1 \) and \( Q^2 \). They are mathematically expressed as follows:

\[ Q = Q^1 + Q^2 \]

\[ Q^1 = \sum_{i=1, j \in J, b \in B} x_{ib} (\beta_{ij} - b) \]

\[ Q^2 = \sum_{i=1, j \in J, b \in B} \sum_{m \in M} rep_{imb} (b - m) + \sum_{i=1, j \in J, b \in B} \sum_{a \in A} (a_{ij} y_{im} - \sum_{b \in B} rep_{imb}) (\beta_{ij} - m) \]
Constraints
\[ V_i + W_i + X_i + Y_i + Z_i = 1, \forall i \]  \hspace{1cm} (22)
\[ B_j + C_j + D_j + E_j = 1, \forall j \]  \hspace{1cm} (23)
\[ \sum_{b \in B} x_{ijb} = W_i, \forall i, j \]  \hspace{1cm} (24)
\[ \sum_{m \in M, t \in T} y_{itm} = V_i, \forall i \]  \hspace{1cm} (25)
\[ \sum_{i \in I} y_{itm} \geq dp_{tm}, \forall m, t \]  \hspace{1cm} (26)
\[ \sum_{i \in I} (x_{ijb} + def_{ijb}) - \sum_{i \in I, m \in M} (rep_{imjb}) + L_{jb} - fr_{jb} \]  \hspace{1cm} (27)
\[ -sc_{jb} - fd_{jb} = dc_{jb}, \forall b, j \]  \hspace{1cm} (28)
\[ \sum_{j \in J} y_{jk}(\sum_{b \in B} r_{jb} + \sum_{i \in I} X_i(a_{ij} + f_{ij}) + fr_{jb}) + sm_k = dm_k, \forall k \]  \hspace{1cm} (29)
\[ fr_{jb} + fd_{jb} = \sum_{i \in I} (V_i + W_i) \times f_{ij}, \forall j \]  \hspace{1cm} (30)

NUMERICAL EXAMPLE
In order to illustrate the formulated model, an example is presented in this section. The ARTODTO system receives 200 EOL Air Conditioners (ACs) for each period. There are four types of air conditioners with their own unique features, but they all have the same function of providing cool air and they all share the following eight components: compressor, condenser, evaporator, control box, blower, air guide, motor, and fan. The different types of air conditioners are: window AC, split AC, packaged AC, and central AC. The input data is given in Tables 1 through 4.

<table>
<thead>
<tr>
<th>Component</th>
<th>Windows AC</th>
<th>Split AC</th>
<th>Packaged AC</th>
<th>Central AC</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaporator</td>
<td>0.17</td>
<td>0.20</td>
<td>0.17</td>
<td>0.17</td>
</tr>
<tr>
<td>Control Box</td>
<td>0.17</td>
<td>0.20</td>
<td>0.17</td>
<td>0.17</td>
</tr>
<tr>
<td>Blower</td>
<td>0.50</td>
<td>0.60</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>Air Guide</td>
<td>0.50</td>
<td>0.80</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>Motor</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>Condenser</td>
<td>0.17</td>
<td>0.50</td>
<td>0.17</td>
<td>0.17</td>
</tr>
<tr>
<td>Fan</td>
<td>0.50</td>
<td>1.00</td>
<td>0.50</td>
<td>0.50</td>
</tr>
<tr>
<td>Compressor</td>
<td>0.17</td>
<td>0.50</td>
<td>0.17</td>
<td>0.17</td>
</tr>
</tbody>
</table>
Table 2: Recycling, holding, outside procurement, disposal costs

<table>
<thead>
<tr>
<th>Component</th>
<th>Recycling Cost</th>
<th>Holding Cost</th>
<th>Outside Procurement Cost</th>
<th>Disposal Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaporator</td>
<td>16</td>
<td>10</td>
<td>175</td>
<td>50</td>
</tr>
<tr>
<td>Control Box</td>
<td>10</td>
<td>2</td>
<td>50</td>
<td>10</td>
</tr>
<tr>
<td>Blower</td>
<td>8</td>
<td>3</td>
<td>100</td>
<td>22</td>
</tr>
<tr>
<td>Air Guide</td>
<td>4</td>
<td>1</td>
<td>40</td>
<td>20</td>
</tr>
<tr>
<td>Motor</td>
<td>10</td>
<td>3</td>
<td>80</td>
<td>28</td>
</tr>
<tr>
<td>Condenser</td>
<td>16</td>
<td>10</td>
<td>500</td>
<td>46</td>
</tr>
<tr>
<td>Fan</td>
<td>8</td>
<td>2</td>
<td>230</td>
<td>11</td>
</tr>
<tr>
<td>Compressor</td>
<td>16</td>
<td>10</td>
<td>370</td>
<td>42</td>
</tr>
</tbody>
</table>

Table 3 Components demands for periods 1, 2 and 3

<table>
<thead>
<tr>
<th>Component</th>
<th>Remaining Life Bins</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Bin 1/2/3</td>
</tr>
<tr>
<td>Evaporator</td>
<td>15/20/10</td>
</tr>
<tr>
<td>Control Box</td>
<td>10/15/10</td>
</tr>
<tr>
<td>Blower</td>
<td>14/10/12</td>
</tr>
<tr>
<td>Air Guide</td>
<td>9/12/15</td>
</tr>
<tr>
<td>Motor</td>
<td>13/12/13</td>
</tr>
<tr>
<td>Condenser</td>
<td>15/10/10</td>
</tr>
<tr>
<td>Fan</td>
<td>10/12/16</td>
</tr>
<tr>
<td>Compressor</td>
<td>15/14/10</td>
</tr>
</tbody>
</table>

The product demands for period 1 are 10, 12, 10 for bin 1, bin 2 and bin 3 respectively for each design alternative, for period 2 are 15, 10, 10 for bin 1, bin 2 and bin 3 respectively for each design alternative, and for period 3 are 15, 15, 12 for bin 1, bin 2 and bin 3 respectively for each design alternative.

Table 4: Material yields and demands for Periods 1, 2 and 3.

<table>
<thead>
<tr>
<th>Components (j)</th>
<th>Plastic</th>
<th>Steel</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evaporator</td>
<td>-</td>
<td>15.00</td>
</tr>
<tr>
<td>Control Box</td>
<td>5.00</td>
<td>-</td>
</tr>
<tr>
<td>Blower</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Air Guide</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Motor</td>
<td>-</td>
<td>12.00</td>
</tr>
<tr>
<td>Condenser</td>
<td>-</td>
<td>20.00</td>
</tr>
<tr>
<td>Fan</td>
<td>-</td>
<td>4.00</td>
</tr>
<tr>
<td>Compressor</td>
<td>-</td>
<td>16.00</td>
</tr>
</tbody>
</table>

| Demand for period 1 | 100.00 | 300.00 |
| Demand for period 2 | 150.00 | 200.00 |
| Demand for period 3 | 100.00 | 250.00 |

RESULTS

The model was solved using LINGO 13.0. Tables 5, 6 and 7 display the values of the performance measures. In period 1, 85 EOL products are disassembled (20 Window ACs, 35 Split ACs, 10 Packaged ACs, and 20 Central ACs), 60 EOL products are remanufactured (10 Window ACs, 35 Split ACs and 15 Packaged ACs), 30 EOL products are recycled (10 Window ACs, 15 Packaged ACs, and 5 Central ACs), 10 EOL products are disposed of (4 Packaged ACs and 6 Central ACs) and 15 EOL products (9 Split ACs and 6 Central ACs) are stored.
Table 5: Values of performance measures in Period 1

<table>
<thead>
<tr>
<th>Goals</th>
<th>Aspiration Level</th>
<th>Step 1</th>
<th>Step 2</th>
<th>Step 3</th>
<th>Step 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total Profit</td>
<td>20000</td>
<td>21568.24</td>
<td>20000.00</td>
<td>20000.00</td>
<td>20000.00</td>
</tr>
<tr>
<td>Quality Level</td>
<td>8000</td>
<td>8486.14</td>
<td>7994.27</td>
<td>8000.00</td>
<td>8000.00</td>
</tr>
<tr>
<td>Disposal Quantity</td>
<td>26000</td>
<td>26681.53</td>
<td>26167.19</td>
<td>25981.32</td>
<td>26000.00</td>
</tr>
<tr>
<td>Material Value</td>
<td>2000</td>
<td>2374.48</td>
<td>2226.34</td>
<td>2187.57</td>
<td>2115.98</td>
</tr>
</tbody>
</table>

In period 2, 78 EOL products are disassembled (20 Window ACs, 38 Split ACs, 6 Packaged ACs, and 14 Central ACs), 50 EOL products are remanufactured (16 Window ACs, 26 Split ACs and 8 Central ACs), 30 EOL products are recycled (15 Split ACs, 8 Packaged ACs, and 7 Central ACs) and 5 EOL products are disposed of (5 Central ACs) and 37 EOL products (13 Window ACs and 24 Central ACs) are stored.

Table 6: Values of performance measures in Period 2

<table>
<thead>
<tr>
<th>Goals</th>
<th>Aspiration Level</th>
<th>Step 1</th>
<th>Step 2</th>
<th>Step 3</th>
<th>Step 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total profit</td>
<td>15000</td>
<td>15100.21</td>
<td>15000.00</td>
<td>15000.00</td>
<td>15000.00</td>
</tr>
<tr>
<td>Quality Level</td>
<td>6000</td>
<td>6721.47</td>
<td>6215.23</td>
<td>6215.23</td>
<td>6215.23</td>
</tr>
<tr>
<td>Disposal Quantity</td>
<td>23000</td>
<td>24511.54</td>
<td>23789.61</td>
<td>22936.17</td>
<td>23000.00</td>
</tr>
<tr>
<td>Material Value</td>
<td>1850</td>
<td>1912.20</td>
<td>1896.32</td>
<td>1885.24</td>
<td>1883.26</td>
</tr>
</tbody>
</table>

In period 3, 108 EOL products are disassembled (30 Window ACs, 45 Split ACs, 20 Packaged ACs, and 13 Central ACs), 53 EOL products are remanufactured (24 Window ACs, 21 Split ACs and 8 Packaged ACs), 17 EOL products are recycled (12 Packaged ACs, and 5 Central ACs) and 13 EOL products are disposed of (7 Split ACs and 6 Packaged ACs) and 9 EOL products (9 Central ACs) are stored.

Table 7: Values of performance measures in Period 3

<table>
<thead>
<tr>
<th>Goals</th>
<th>Aspiration Level</th>
<th>Step 1</th>
<th>Step 2</th>
<th>Step 3</th>
<th>Step 4</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total profit</td>
<td>22500</td>
<td>23456.18</td>
<td>22500.00</td>
<td>22500.00</td>
<td>22500.00</td>
</tr>
<tr>
<td>Quality Level</td>
<td>9100</td>
<td>9054.21</td>
<td>9026.78</td>
<td>9100.00</td>
<td>9100.00</td>
</tr>
<tr>
<td>Disposal Quantity</td>
<td>26500</td>
<td>26895.40</td>
<td>26721.47</td>
<td>26534.18</td>
<td>26534.18</td>
</tr>
<tr>
<td>Material Value</td>
<td>2000</td>
<td>2458.47</td>
<td>2395.76</td>
<td>2264.21</td>
<td>2187.53</td>
</tr>
</tbody>
</table>

For all the three periods, split AC was the most preferred design alternative for fulfilling all the demands while satisfying all the constraints. In total, 106 split ACs were disassembled, 82 were remanufactured, 15 were recycled, none was disposed of and 16 were stored for the future.

CONCLUSION

The proposed model evaluated the design alternatives of air conditioner for ease of disassembly in order to meet the products, components and materials demands while satisfying physical, financial and environmental constraints. To take into account different factors of design alternatives, the model used a disassembly factor which is defined as the number of assemblies to disassemble divided by the total number of assemblies in the product. Consideration of these factors during the design phase will increase the efficiency of the disassembly process. The proposed model is flexible to various costs and deals with the uncertainty of conditions of received EOL products’ using sensors. In the example given here, the model preferred split air conditioner over windows, packaged and central air conditioners to fulfill most of the demands.
REFERENCES


IMPACT OF INFORMATION SHARING AND ORDERING POLICIES ON A SUPPLY CHAIN

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ABSTRACT

We study the impact of information sharing and ordering policies on a supply chain (SC) in terms of bullwhip effect (BWE), systemic average inventory (Sys Avg Inv) and average fill rate (Avg FR) using a systems dynamic approach. A SC with three echelons is used with order-up-to-S level (OUT-S) and Synchronized Anker-and-Adjust (Sync-AaA) ordering policies. The demand at each echelon is forecasted using an exponential smoothing (ES) method. The simulation results show that information sharing is the most critical factor regardless ordering policies in terms of BWE and other performance measures. When customer forecasting information is shared, the performance of Sync-AaA and OUT-S policies is comparable in terms of Sys Avg Inv and Avg FR. The main advantage of Sync-AaA over OUT-S is that it consistently generates lower and more robust BWE.

Key words: Systems Dynamic Simulation, Bullwhip Effect, Supply Chain, Exponential Smoothing, Information Sharing.

INTRODUCTION

Inventories in a supply chain (SC) are sensitive to demand change. Small changes in a customer order can create large fluctuations and oscillations in inventory and replenishment orders in upstream echelons in SC. Particularly, the phenomenon that the amplification of demand variability at each echelon increase as one moves up the SC from downstream to upstream echelons is called bullwhip effect (BWE). It was originally observed in industry by Forrester (1961). Lee, Padmanabhan, and Whang (1997) discussed four sources for BWE–demand signal process, order batching, price variations, and rationing game. Chen, Ryan, and Simchi-Levi (2000a; 2000b) mathematically proved that BWE exists in a simple SC model of a retailer and a manufacturer with the order-up-to inventory policy. They showed that BWE increases with lead time being longer between retailer and manufacturer and the demand forecasting being less smooth at the retailer. Dejonckheer et al. (2004) compared order-up-to (OUT) and smoothing replenishment ordering policies in a four-echelon SC with a retailer, a wholesaler, a distributor and a factory. According to their results, BWE increases for both policies when no forecasting information at retailer is shared. However, when the forecasting information is shared, the reduction of BWE in case of the smoothing replacement ordering policy is very significant, and it can generate almost flat BWE across all echelons based on specific parameter settings while BWE in case of the OUT policy still increases at upstream echelons even with information sharing. Paik and Bagchi (2007) statistically identified six significant causes of BWE–demand forecasting, order batching, material delay, information delay, purchasing delay, and level of echelons–using simulation with the four-echelon SC as in Dejonckheer et al. (2004). Wangphanich, Kara, and Kayis (2010) showed that the Vendor Management Inventory (VMI) system and the small lot size in Material Requirement Planning (MRP) can reduce BWE significantly through their multi-product, multi-state SC using simulation. Hussain and Saber (2012) and Hussain, Drake, and Lee (2012) used a systems dynamic (SD) simulation approach to the multi-echelon supply chain with the Automatic Pipeline Feedback Order-Based Production...
Control System (APIOBPCS) and statistically showed that any time delay related decision for production, inventory, forecasting, information sharing, and batch size is a significant cause of BWE. Barlas and Gunduz (2011) used a three-echelon SC model with a simple exponential smoothing forecasting method to evaluate BWE under three different ordering policies—order-up-to-S level, anchor-and-adjust, and (s, S). They found that sharing the customer demand forecasting information significantly reduces BWE across those ordering policies.

Cannella and Ciancimino (2010) evaluated three different four-echelon SC configurations (i.e. traditional without demand forecasting information sharing, information exchange with demand forecasting information sharing, and synchronized with all on-hand inventory and WIP information sharing across echelons on top of the information exchange configuration) with the smoothing replacement ordering policy. According to them, synchronized SC configuration showed the highest fill rate, smallest systemic zero replenishment, and smallest systematic average inventory as well as the lowest level of BWE among all configurations. Further, they also identified that as order smoothing increases, the SC operational performance measures (BWE, average inventory, and zero replenishment) improve while the customer service level represented by fill rate becomes worse. Cannella et al. (2013) proposed the BWE measurement system where all performance metrics are classified into one of the four categories created by the two criteria—1) criterion assessment (internal process efficiency or customer satisfaction metrics) and 2) SC level (single echelon or whole SC level). For example, the fill rate at retailer is categorized in (customer satisfaction, whole echelon level) while the average inventory in (internal process efficiency, single echelon level). Then, they evaluated the three-echelon SC used by Barlas and Gunduz (2011) with the smoothing replenishment order policy using their performance measurement system.

Research on BWE is still active. Based on several mathematical foundations by Lee et al. (1997) and Chen et al. (2000a; 2000b), many authors have attempted to identify causes of BWE and used one or more specific ordering policies to evaluate them (Dejonckheer et al. 2004; Hussain and Saber 2012; Hussain et al. 2012; Barlas and Gunduz 2011). We believe that it is important to understand the causes of BWE since it negatively affects SC performance. However, it is also very important to understand how to remove or reduce BWE by minimizing negative impact on other performance measures in SC. For example, as Barlas and Gunduz (2011) mentioned, BWE can be significantly reduced or eliminated by smoothing the replenishment orders. However, this may negatively affect the service level in the SC. In fact, Cannella and Ciancimino (2010) and Cannella et al. (2013) are few authors who investigated BWE avoidance strategies by considering the overall impact on SC. We advocate that BWE should be analyzed and studied from the overall SC perspective to avoid or minimize any negative impact on SC since many performance measures in SC are interrelated. Further, we recognize that a different ordering policy may have different impact on SC in terms of BWE, other performance measures, and information requirements. Hence, to improve our overall understanding on SC from the information and ordering policies perspective, we study a SC model with different ordering policies—order-up-to-S level and Synchronized anchor-and-adjust, and analyze their corresponding BWE pattern and impact on other important SC performance measures such as systemic average inventory level and customer service level.

**MODELING**

We consider a three-echelon supply chain system with identical serially connected agents (or echelons)—a retailer, a wholesaler, and a producer. Following assumptions are used:

- The stocking capacity at any echelon is unlimited.
- Each agent in an echelon works independently. It forecasts its demand if there is no information shared, and based on the replenishment order from an immediate downstream echelon, it ships its goods if inventory is available, and places a replenishment order to an immediate upstream echelon.
• Partial fulfillment of an order and backlogs are allowed. For example, when a downstream echelon sends an order, its upstream echelon ships goods immediately upon receiving the order if there is enough on-hand inventory. Otherwise, that order may be partially fulfilled based on the inventory availability, and any unfulfilled portion of the order is backlogged without any loss.
• The uppermost echelon (a producer) places an order to an unlimited source, so there is no backlogging in the uppermost echelon.
• There is no time delay between any order receipt and the order shipping if inventory is available.
• The transit capacity between adjacent echelons is unlimited.

The Equations (1) to (17) define the different state variables at each echelon $i$ in each period $t$ where $i = 1, \ldots, 3$; $i = 1, 2, 3$ represents the retailer, wholesaler and producer, respectively while $i = 0$ stands for the customer. For simplicity and consistency, our simulation time in the model is modelled as discrete time (DT), set to one—that is, all states in the model are updated at every $DT = 1$.

In each period $t$, on-hand inventory at echelon $i$, $OH(i, t)$, is determined by the arrival quantity of shipment from its upstream echelon, $AR(i, t)$, and shipment quantity of goods to a downstream echelon, $SP(i, t)$ as follows:

$$OH(i, t) = OH(i, t-1) + (AR(i, t) - SP(i, t))$$

(1)

In-transit inventory, $IT(i, t)$, represents the inventory in transportation from an upstream echelon

$$IT(i, t) = IT(i, t-1) + (SP(i+1, t) - AR(i, t))$$

(2)

Shipment requirement, $SR(i, t)$, is the sum of demand, $D(i, t)$, with the backlogged orders, $BL(i, t)$. That is, this is the quantity that needs to be fulfilled.

$$SR(i, t) = D(i, t) + BL(i, t)$$

(3)

If there is any inventory available, it is shipped immediately to its downstream echelon whenever requested. However, actual shipment to a downstream echelon, $SP(i, t)$, is constrained by the on-hand inventory availability as follow:

$$SP(i, t) = \min\{OH(i, t), SR(i, t)\}$$

(4)

Any unfulfilled portion of inventory, $D(i, t) - SP(i, t)$, is added to the backlogged orders, $BL(i, t)$

$$BL(i, t) = BL(i, t-1) + \max(0, D(i, t) - SP(i, t))$$

(5)

Net inventory, $IL(i, t)$, is the inventory level after the backlogged orders are deducted from the on-hand inventory, $OH(i, t)$.

$$IL(i, t) = OH(i, t) - BL(i, t)$$

(6)

It is assumed that an echelon uses a simple exponential smoothing (ES) forecasting method to calculate the expected demand, $ED(i, t)$, based on a real order from its downstream echelon. The smoothing factor, $\alpha$, in the ES forecasting method is decided by the Expectation Adjustment Time in the model.

$$ED(i, t) = ED(i, t-1) - \alpha(D(i, t) - ED(i, t-1))$$

(7)

Then, the demand during the lead time, $LD(i, t)$, is simply represented by
\[ LD(i, t) = ED(i, t) \times LT(i, t) \] (8)

, where \( LT(i, t) \) is the transportation lead time, \( LT(i, t) = LT \) since it is set to two in this study.

In the order-up-to-S level (OUT-S) policy, whenever an agent places a replenishment order to an upstream echelon, it needs to order the quantity needed to bring its inventory position, \( IP(i, t) \), to the pre-determined base-stock level, \( S \). Each echelon continuously monitors its inventory position, \( IP(i, t) \), which is defined as

\[ IP(i, t) = OH(i, t) + (IT(i, t) + BL(i, t+1)) - BL(i, t) \] (9)

, where \( IT(i, t) + BL(i, t+1) \) represents the difference between the total quantity of orders placed to an upstream echelon and the one that has arrived to echelon \( i \) at time \( t \). That is, it is the total number of outstanding goods.

At each echelon \( i \), the order-up to \( S \) level, \( S(i, t) \), is defined as the multiple of the expected demand, \( ED(i, t) \),

\[ S(i, t) = (LT(i, t) + K_i) \times ED(i, t) \] (10)

, where \( K_i \) is a constant, called the safety stock factor, controlling the safety stock level against the demand during the lead time.

Therefore, the actual quantity to order under OUT-S policy is decided by

\[ O(i, t) = \max \{ (S(i, t) - IP(i, t)), 0 \} \] (11)

The anchor-and-adjust (AaA) policy attempts to stabilize each echelon’s inventory level and WIP (orders in transit between echelons) by using a target inventory and a target WIP at each echelon. However, in our study, we extend this concept to all downstream echelons. For example, an echelon shares all current and target inventories and WIP information from its downstream echelons beyond the demand information, and use all information to make its replenishment order quantity. When this is feasible, Cannella and Ciancimino (2010) called it as a synchronized SC configuration. In this sense, we call this ordering policy as the Synchronized anchor-and-adjust (Sync-AaA), and it is the same of the smoothing replenishment ordering policy in Cannella and Ciancimino (2010). Let \( TIL(i, t) \) and \( TIT(i, t) \) be the target inventory level and the target WIP level, respectively at echelon \( i \) at time \( t \). The virtual inventory level, \( vIL(i, t) \), and the virtual WIP, \( vIT(i, t) \), at echelon \( i \), are defined as the sum of all inventory levels and all WIPs at echelon \( i \) and its downstream echelons, respectively:

\[ vIL(i, t) = \sum_{j=1}^{i} IL(j, t) \] (12)

\[ vIT(i, t) = \sum_{j=1}^{i} IT(j, t) \] (13)

Target virtual inventory level and target virtual WIP are defined respectively by:

\[ TvIL(i, t) = \sum_{j=1}^{i} TIL(j, t) = ED(1, t) \sum_{j=1}^{i} T(j) \] (14)

\[ TvIT(i, t) = \sum_{j=1}^{i} TIT(j, t) = ED(1, t) \sum_{j=1}^{i} LT(j, t) \] (15)

Note that both virtual inventory level and virtual WIP require significant information from all downstream echelons. Hence, it is reasonable to assume that all echelons share the customer demand information too. That is why we use the forecasted demand at the retailer, \( ED(1, t) \), for Equations (14) and (15). \( T(j) \) is the
cover time for inventory control, referred to as the inventory cover time (ICT) at echelon \( j \). It plays a role as a safety stock factor as \( K_i \) in \( OUT-S \) policy. As it increases, an echelon attempts to order a high amount of order quantity based on Equation (16).

Eventually, the order quantity under \( Sync-AaA \) policy is determined by

\[
O(i, t) = \max\{ED(1, t) + \frac{T_{WI}(i, t) - v_N(i, t)}{T_{WI}^I}, 0\}
\]

where \( T_{WI}^I \) and \( T_{WI}^I \) are referred to as the inventory proportional controller and WIP proportional controller, respectively. \( T_{WI}^I \) and \( T_{WI}^I \) are a smoothing constant for difference between the target virtual inventory and the virtual inventory, and for difference between target virtual WIP and the virtual WIP, respectively.

Note that when there is no information shared, an echelon \( i \) forecasts its demand, \( D(i, t) \), which is the replenishment order quantify from its immediate downstream echelon. Hence,

\[
ED(i, t) = \hat{O}(i - 1, t), \quad i = 1, 2, 3
\] (17)

If customer information is shared across echelons, \( ED(1, t) = \hat{O}(0, t) \) is used at all echelons to decide their order quantity. Note that \( O(0, t) \) is the actual customer demand.

The \textit{iThink} software is used to model SC in this study. Figure 1 shows an example of BWE observed in the model with \( OUT-S \) policy based on \( K_i = 2.25 \), without information sharing (\( Info = 0 \)), and smoothing constant, \( \alpha = 0.7 \) in ES forecasting. The figure displays all orders at each echelon against the actual customer demand to the retailer over time. The “demand” is the actual demand placed by customers. The “Order at RT”, “Order at WS”, and “Order at PD” are the quantity of replenishment orders placed by the retailer, wholesaler, and producer, respectively. We can observe that the magnitude of order oscillation increases when one moves up from retailer to producer, and this is consistent with the results observed by many other researchers.

![Figure 1. Bullwhip effect \((K_i = 2.25; Info = 0; \alpha = 0.7)\)](image)

**EXPERIMENTS**

The following performance metrics are used. BWE at each echelon is defined by Chen et al. (2000b) in Equation (18). It is the ratio of the coefficient of variation of orders at echelon \( i \), \( \sigma_{O,i}^2 / \mu_{O,i} \) to the coefficient
of variation of customer demand, \( \sigma_{d,i}^2/\mu_{d,i} \). Disney and Towill (2003) note that for a stationary demand over long periods of time, the average demand of order, \( \mu_{o,i} \), converges to the average of customer demand, \( \mu_d \). This corresponds to (internal process efficiency, single echelon level) category according to Cannella et al. (2013).

\[
\text{BWE at echelon } i = \frac{\sigma_{o,i}^2/\mu_{o,i}}{\sigma_d^2/\mu_d} 
\]

In addition to BWE, this study uses the inventory and fill rate as a performance metric to evaluate ordering policies and their impact on SC. The systemic average inventory (Sys Avg Inv) is the sum of the average inventory values of all echelons in the SC, categorized in (internal process efficiency, whole SC level) by Cannella et al (2013), defined by

\[
\text{Sys Avg Inv} = \sum_i \frac{1}{TL} \sum_{t=0}^{T_L} OH(i,t) 
\]

While Sys Avg Inventory and BWE are performance metrics representing the internal process efficiency in a SC, fill rate is a performance metric representing customer satisfaction at whole SC level (Cannella, 2013; Zipkin, 2000). It is the ratio of sales delivered to customer on time including partial fulfillment to the customer demand, and evaluated at every time unit. Therefore, it is measured at the retailer only. The average fill rate (Avg FR) is the average of FR over time defined by:

\[
\text{Avg FR} = \frac{1}{TL} \int_0^{T_L} \frac{C_0(t)}{D(0,t)} \, dt 
\]

, where \( D(0,t) \) is customer demand at echelon \( i = 0 \) at time \( t \) while \( C_0(t) \) is the satisfied demand among \( D(0,t) \) without any delay. \( TL \) is time duration where FR is observed.

The following parameters are used for all simulations:

- The customer demand to the retailer is normally distributed with mean 20 and standard deviation 2.
- The transit lead times (LT) between echelons are deterministic (LT = 3).
- Each model runs for 256 time units.

In addition, the following additional parameters and information are used:

- We have two different SC configurations: one with \( OUT-S \) and the other with \( Sync-AaA \) policy for all echelons.
- A simple exponential smoothing (ES) forecasting method is used for all configurations with the following forecasting smoothing factor, \( \alpha \) set to (0.1, 0.3 and 0.5).
- The customer demand forecasting at retailer is shared across all echelons (\( Info = 1 \)) or each echelon forecasts its own demand (\( Info = 0 \)).
- The Safety Stock (SS) level is controlled by the safety stock factor, \( K_i \), and it varies (2.00, 2.25, 2.50) in case of \( OUT-S \) policy.
- \( T(j) \), the cover time for inventory control at echelon \( j \), set to (1.00, 1.15, 1.30) in case of \( Sync-AaA \) policy.
- \( T_{w}^i = T_{y}^i = 3 \), for all \( i \) in case of in case of \( Sync-AaA \) policy.

**RESULTS AND ANALYSIS**

Based on the inputs described above, the SC configuration with \( OUT-S \) policy has 18 different parameter
settings while the SC configuration with Sync-AaA policy has 9 different settings. The simulation results from OUT-S policy are summarized in Tables 1 and 2 while those from Sync-AaA policy in Table 3.

<table>
<thead>
<tr>
<th>$K_i = 2.50$</th>
<th>$K_i = 2.25$</th>
<th>$K_i = 2.00$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$</td>
<td>BWE</td>
<td>Avg FR</td>
</tr>
<tr>
<td>-------------</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>0.1</td>
<td>3.37</td>
<td>7.44</td>
</tr>
<tr>
<td>0.3</td>
<td>7.03</td>
<td>38.34</td>
</tr>
<tr>
<td>0.5</td>
<td>13.34</td>
<td>103.15</td>
</tr>
</tbody>
</table>

Table 1. Results from order-up-to-S level when Info = 0

<table>
<thead>
<tr>
<th>$K_i = 2.50$</th>
<th>$K_i = 2.25$</th>
<th>$K_i = 2.00$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$</td>
<td>BWE</td>
<td>Avg FR</td>
</tr>
<tr>
<td>-------------</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>0.1</td>
<td>3.37</td>
<td>7.44</td>
</tr>
<tr>
<td>0.3</td>
<td>7.03</td>
<td>8.58</td>
</tr>
<tr>
<td>0.5</td>
<td>13.34</td>
<td>15.85</td>
</tr>
</tbody>
</table>

Table 2. Results from order-up-to-S level when Info = 1

<table>
<thead>
<tr>
<th>$ICT_i = 1.30$</th>
<th>$ICT_i = 1.15$</th>
<th>$ICT_i = 1.00$</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\alpha$</td>
<td>BWE</td>
<td>Avg FR</td>
</tr>
<tr>
<td>0.1</td>
<td>2.39</td>
<td>3.44</td>
</tr>
<tr>
<td>0.5</td>
<td>2.56</td>
<td>4.68</td>
</tr>
</tbody>
</table>

Table 3. Results from Anker-and-Adjust when Info = 1

From the results with OUT-S policy, BWE increases when the safety stock factor, $K_i$, increases according to Equation (10), introducing a larger ordering quantity according to Equation (11). Figure 3 clearly shows that BWE geometrically increases at higher level of echelons (note that 1: retailer, 2: wholesaler, 3: producer) when no customer forecasting information is shared. This upward trend gets more apparent with $K_i$ being larger. Note that BWE in Figure 3 is average value across all smoothing constants ($\alpha$) in Tables 1. Figure 4 displays the impact of information sharing on BWE with $K_i$ being set to 2.5. Other $K_i$ values show the same pattern (not displayed). With information sharing, BWE significantly reduces to a linear pattern from the geometrically increasing pattern.

![Figure 3. BWE by Safety Stock Factor without information sharing ($K_i=K_i$)](image)

![Figure 4. BWE with-and-without information sharing at $K_i=2.5$.](image)

Figures 5 and 6 use average BWE for each forecasting smoothing constant, computed across all $K_i$’s, to show the impact of $\alpha$ without and with information sharing, respectively. As the smoothing constant
increases, BWE increases at all echelons for both cases. However, it geometrically increases without information sharing while it linearly increases with information sharing. According to Equation (7), when \( \alpha \) increases, the resulting demand forecasting will have higher variation, leading to higher level of BWE. The results from Figures 5 and 6 also indicate that an order smoothing technique reduces BWE although its impact on BWE is significantly less when information is shared. Our results are consistent with those from Chen et al. (2000a; 2000b).

Figures 7 and 8 display average BWE by safety stock factor \((K_i)\) and ICT computed across smoothing constants, respectively. Note that we can estimate the impact of \(K_i\) and ICT on the order quantity from Equations (10) and (14), respectively. We observe that even when information is shared, BWE slightly increasingly propagates at higher echelons regardless ordering policies—note that setting appropriate parameters is beyond the scope of this paper. Further, BWE is not sensitive to safety stock factor \((K_i)\) nor ICT when information is shared. Figure 8 indicates that \(\text{Sync-}\text{AaA}\) policy is more robust in terms of BWE when safety stock changes.

Figure 9 shows that BWE also linearly propagates at higher echelons along with \( \alpha \) in case of \(\text{Sync-}\text{AaA}\). That is, an order smoothing reduces BWE in case of \(\text{Sync-}\text{AaA}\) as in \(\text{OUT-S}\) policy. However, when we compare Figure 9 with Figure 6, we observe that the impact of the order smoothing on BWE is higher in \(\text{OUT-S}\) than \(\text{Sync-}\text{AaA}\).

Figures 10 and 11 show the behavior of Avg FR and Sys Avg Inv at each \( \alpha \), respectively. Note that all are averaged values across all safety stock factors and ICT’s at \( \alpha \). In terms Avg FR with \(\text{OUT-S}\), we first can observe that order smoothing negatively affects Avg FR particularly without information sharing. Information sharing mitigates this negative impact. With \(\text{Sync-}\text{AaA}\), Avg FR is higher than any other cases. However, order smoothing also negatively affects Avg FR while its impact becomes flat. Second, we can see that Avg FR without information sharing in case of \(\text{OUT-S}\) policy is similar to that with information.
sharing particularly at \( \alpha = 0.1 \) and 0.3. However, it shows that the value is 8% higher than that with information sharing at \( \alpha = 0.5 \). Why this happens? Does information sharing negatively affect Avg FR? It is very important to recognize that Avg FR is significantly related to Sys Avg Inv. Hence, we also need to check Sys Avg Inv level in Figure 11 to see how many inventories are used to generate a specific Avg FR. According to Equation (7), when \( \alpha \) increases, it introduces higher level of variations, resulting in higher inventory (Equation 10), which could increase Avg FR too. According to Figure 11, the case of \textit{OUT-S} policy with information sharing uses the lowest level of inventories, but generating similar or lower Avg FR than the case with the same policy without information sharing while the case without information sharing uses a significantly large number of inventories to generate similar or slightly higher Avg FR displayed in Figure 10—specifically, the \textit{OUT-S} case without information sharing uses 154.74 inventories while the same policy with information sharing uses only 78.30 inventories when \( \alpha \) is set to 0.5. Note that the \textit{Sync-AaA} case is between these two, but much closer to the \textit{OUT-S} case with information sharing. Figure 11 also shows that two policies with information sharing are very robust in terms of Sys Avg Inv when a smoothing constant changes.

![BWE (AoA) by Alpha](image1)

![Avg FR](image2)

![Sys Avg Inv](image3)

![Comparison of All Alternatives](image4)

From Figures 5, 6, 9, 10, and 11, we can observe the following general pattern. BWE decreases when forecasting uses less smoothing constants, generating smoother order (Figures 5, 6, and 9). However, this BWE reduction negatively affects Avg FR (Figure 10) but improves Avg Sys Inv (Figure 11). However when information is shared, the impact of a smoothing constant (or order smoothing) on BWE, Avg FR, and Sys Avg Inv decreases.

We compare the performance of two ordering policies using Figure 12. Figure 12 displays the results of six different cases—three information sharing cases of \textit{OUT-S} policy at three different \( K_i \)'s and three cases of
Sync-AaA at three different ICT’s—in terms of Avg FR, Sys Avg Inv and Total BWE. Note that Total BWE is sum of all BWE’s across echelons to show whole SC level impact, and all performance measures are the average across all smoothing constants. We are using this figure for overall comparison since each ordering policy uses a different set of parameters, thus it is difficult to have the same test conditions in terms of those parameters. Based on the experiments, we make the following conclusions:

- In general, all cases with Sync-AaA policy generate lower BWE compared to those with OUT-S policy (Figure 12).
- The sync-AaA policy is also more robust than OUT-S policy in terms of order smoothing and inventory change.
- Regardless ordering policies, Avg FR increases when Sys Avg Inv increases (Figure 12), and the ratio of Avg FR to Sys Avg Inv is similar for both policies when information is shared. This indicates that information sharing is a more important factor than any ordering policy in terms of Avg FR and Sys Avg Inv. For example, without information sharing, Avg FR can still improve (increase) with a significantly higher amount of inventories than the equivalent cases with information sharing.
- Once information is shared, the main advantage of Sync-AaA policy over OUT-S policy is reduction of BWE.
- An order smoothing decreases BWE. However, it also negatively affects Avg FR while it improves Sys Avg Inv for both ordering policies as observed in Cannella and Ciancimino (2010). However, its impact reduces when information is shared.

CONCLUSIONS

In this study, we have studied the impact of information sharing and ordering policies on the supply chain in terms of bullwhip effect (BWE), systemic average inventory (Sys Avg Inv) level, and average fill rate (Avg FR) using the iThink systems dynamic simulation approach. The order-up-to-S level (OUT-S) and Synchronized anker-and-adjust (Sync-AaA) ordering policies are used in the three echelon supply chain (SC) consisting of a retailer, a wholesaler, and a producer. Each echelon forecasts its demand from downstream using an exponential smoothing method. When information is shared, the customer demand forecasting information at the lowest is shared across all echelons to make ordering decisions to their upstream echelons.

Through this simulation study, we identify that information sharing is the most critical factor in reducing BWE and improving Sys Avg Inv. When information is shared, there is not much difference between Sync-AaA and OUT-S policies in terms of Sys Avg Inv and Avg FR. Under our test conditions, Sync-AaA also generates higher Avg FR but using a slightly higher Sys Avg Inv than OUT-S. The main difference between these two ordering policies is that Sync-AaA policy generates much lower and more robust BWE than OUT-S policy under all test configurations. Its BWE is more robust against forecasting smoothing constant changes and safety stock changes. Although Sync-AaA shows more robust result in terms of BWE, it should be also recognized that it also requires highest level of information requirement. Therefore, decision makers need to consider this trade-off when they design a SC. Future work would include further research on different ordering policies and forecasting methods.

ACKNOWLEDGEMENTS

This material is based upon work that is supported by the National Institute of Food and Agriculture, U.S. Department of Agriculture, under project number SCX 3130315.
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MODELING OF ALTERNATIVE MATERIAL SELECTIONS FOR ENVIRONMENTALLY-FRIENDLY AND ECONOMICAL ASSEMBLY/DISASSEMBLY EVALUATIONS

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ABSTRACT

Environmentally conscious manufacturing has been expected and required in order to deal with material starvation by designing sustainable products. One of the design issues for the sustainable products are to reduce impacts on environmental loads including in the manufacturing phase and to promote recycling after usage phase by selecting recyclable materials. For this reasons, it needs to integrate design and manufacture phases for sustainable products. On the other hand, products design phase assesses about 80% of product life cycle costs. Thus, alternative design for sustainable products needs to evaluate in terms of production costs and environmental aspect, simultaneously. In particular, materials for each part are very important, and decide procurement cost and environmentally impacts.

This study addresses alternative system design by material selection in products design, formulates alternative material selection for evaluating in product design and discusses impacts on environmental loads by changing materials of parts. First, design alternatives in terms of changing material types for each part are addressed, and procurement/assembly/recycling costs and recyclable weights estimated respectively. Second, material selection for evaluating alternatives is formulated as a bi-objective problem. Finally, design alternatives are compared from the viewpoints of environmental and economical aspects.

Keywords: Assembly Reliability Evaluation Method, Recyclability Evaluation Method, Sustainable manufacturing, Assembly Product, Bi-Objective Decision Making Problem

INTRODUCTION

In 2015 in EU Circular Economy Package was announced to promote recycling, so that environmentally conscious manufacturing, which deals with green principles that are concerned with developing methods for manufacturing products from conceptual design to final delivery to consumers [1], has been expected and required in order to overcome material starvation. For assembly products recycling, disassembly is essential phase to sort parts made of different material type, because material recycling requires different process for each material types. Also, disassembly cost tends to be higher due to manual operations for complex tasks [2]. To establish recycling environmentally friendly and economically, disassembly parts selection for minimizing recycling cost, while maximizing recycling rate is often carried out [3][4]. The recycling rate and cost depend on material type decided at product design phase. Moreover, product design phase assesses about 80% of product life cycle costs [5]. Hence, to conduct material recycling more effectively, it requires to consider alternative material selection in terms of environmental and economical aspects by integrating product design and manufacturing phases [6]. However, change of material can increase assembly and procurement costs in production phase. Therefore, material selection have to been evaluated in both assembly and disassembly systems.

This study addresses alternative system design by material selection in products design, formulates alternative material selection for evaluating in product design and discusses impacts on
environmental loads by changing materials of parts. First, design alternatives in terms of changing material types for each part are addressed, and procurement/assembly/recycling costs and recyclable weight are estimated respectively. Second, material selection for evaluating alternatives is considered as bi-objective problem and formulated by goal programming [7]. Finally, design alternatives are compared from the viewpoints of environmental and economical aspects.

**FORMULATION OF ALTERNATIVE MATERIAL SELECTION ENVIRONMENTALLY-FRIENDLY AND ECONOMICAL ASSEMBLY/DISASSEMBLY EVALUATIONS**

This study proposes alternative material selection for environmentally friendly and economical assembly/disassembly evaluations.

A summary of the notations in this study is here as below:

- $J$: Set of parts/tasks, $J = \{1, 2, \ldots, |J|\}$
- $M$: Set of materials, $M = \{1, 2, \ldots, |M|\}$
- $ac_{mj}$: Assembly cost of material $m$ at part $j$
- $pc_{mj}$: Procurement cost of material $m$ at part $j$
- $r_{mj}$: Recyclable weights of material $m$ at part $j$
- $PC$: Production cost
- $PC_{\text{default}}$: Production cost at default design
- $PC_0$: Tolerable production cost
- $PC_s$: Sufficient production cost
- $R$: Recyclable weights
- $R_{\text{default}}$: Recyclable weights at default design
- $R_0$: Tolerable recyclable weights
- $R_s$: Sufficient recyclable weights
- $pm_{mj}$: Parameter; 1 if material $m$ at part $j$ is available for alternative design, else 0
- $x_{mj}$: Binary value; 1 if material $m$ at part $j$ is selected, else 0
- $d^-_1, d^-_2$: Deviational variable between the production cost $PC$ and sufficient recycling cost $PC_s$
- $d^+_2, d^+_2$: Deviational variable between the recyclable weights $R$ and sufficient recyclable weights $R_s$
- $d$: Maximum deviational variable
- $\alpha$: Coefficient between assembly and procurement costs
- $\beta$: Parameter to weight the average and the maximum of $d$

The proposed alternative material selection in this study has 2 objective functions: minimizing production cost including assembly and procurement costs, and maximizing recyclable weights as shown in Eqs. (1) and (2). The parameter $\alpha$ in Eq. (1) means a coefficient between the assembly and procurement costs.

\[
PC = \sum_{m \in M} \sum_{j \in J} (ac_{mj} + \alpha pc_{mj}) x_{mj} \rightarrow \text{Min}
\]  

\[
R = \sum_{m \in M} \sum_{j \in J} r_{mj} x_{mj} \rightarrow \text{Max}
\]  

To solve a bi-objective problem for minimizing the production cost $PC$, while maximizing the recyclable weights $R$, this study applies goal programming [3][7] to the bi-objective alternative material selection. Then, the objective functions as shown Eqs. (1) and (2) and the constraints are formulated as follows.
1. The first goal is to minimize production cost $PC$.

The production cost $TC$ is defined as a sum of assembly and procurement costs of material $m$ at part $j$. The tolerable production cost $PC_0$ is set to be greater than the sufficient production cost $PC_s$, so that as the production cost $PC$ is equal to or under the sufficient production cost $PC_0$ as shown Eqs. (3) and (4). The $d_j^+$ and $d_j^-$ are deviational variables that show differences in the sufficient production cost $PC_s$. By minimizing $d_j^+$, the production cost $PC$ tries to reach the sufficient production cost $PC_s$ as shown in Eq. (5). The differences between tolerable and sufficient production cost ($PC_0 - PC_s$) is used to normalize the deviation variables for achieving different goals, simultaneously. Therefore, the first goal can be formulated as follows:

Goal: minimize $d_1^+$

Subject to:

$$PC_s < PC_0$$

$$PC \leq PC_0$$

$$PC + (PC_0 - PC_s)(d_j^- - d_j^+) = PC_s$$

2. The second goal is to maximize recyclable weights $R$.

In contrast to the formulations of minimizing production cost as shown in Eqs. (3) and (4), the tolerable recyclable weights $R_0$ is set to be under the sufficient recyclable weights $R_s$, and the recyclable weights $R$ is equal to or greater than the tolerable recyclable weights $R_0$ as shown in Eqs. (6) and (7). The recyclable weights $R$ tries to reach the sufficient recyclable weights $R_s$ by minimizing $d_2$ as shown in Eq. (8). Therefore, the second goal can be formulated as follows:

Goal: minimize $d_2^-$

Subject to:

$$R_0 < R_s$$

$$R \geq R_0$$

$$R + (R_s - R_0)(d_2^- - d_2^+) = R_s$$

There are other 2 constraints for alternative material selection. Constraint Eq. (9) represents to limit selectable materials as alternatives. Additionally, constraint Eq. (10) means only one material is selected for all parts.

$$x_{mj} \leq pm_{mj} \quad \forall j \in J, \forall m \in M$$

$$\sum_{m \in M} x_{mj} = 1 \quad \forall j \in J$$

Other constraint equations for minimizing the production cost $PC$ and maximizing the recyclable weights $R$ are set as Eqs. (11), (12), (13), (14), (15) and (16) as well as Kinoshita et al. (2016) [3]. A parameter to weight the average and the maximum of $d$ is here set as $0.5$.

$$x_{mj} \in \{0, 1\} \quad m \in M, j \in J$$

$$d_1^+, d_2^+, d_2^- \geq 0$$

$$\beta d_1^+ + d_2^- + (1 - \beta)d \rightarrow \text{Minimize}$$

$$d \geq d_1^+$$
ALTERNATIVE MATERIAL SELECTION FOR ENVIRONMENTALLY-FRIENDLY AND ECONOMICAL ASSEMBLY/DISASSEMBLY EVALUATIONS: CASE OF CLEANER

This sections applies a cleaner [9] to the alternative material selection for environmentally friendly and economical assembly/disassembly evaluations, and discusses the results from the viewpoints of environmental and economical aspects.

Problem example

The assembly cost and procurement cost is estimated by using Assembly Reliability Evaluation Method (AREM) [10] and Census of Manufacture. In order to examine the effect of disassembly system by alternative material selection, not only the recyclable weights but also the recycling cost is also estimated by Recyclability Evaluation Method (REM) [11]. AREM and REM are methods and software provided by Hitachi Ltd. for estimating assembly, recycling costs and recyclable weights for each part by inputting assembly/disassembly tasks, material types and weights [10][11]. The recycling cost includes disassembly cost, disposal cost, landfill cost and sales of materials for each part [11]. Therefore, the total cost becomes the sum of the production and recycling costs.

The cleaner has 23 original parts, and are made of 8 different materials such as Polypropylene (PP), Methacrylic resin (PMMA), Vinyl chloride resin (PVC), Polystyrene (ABS), Motor, Al/Al alloy, Rubber, Cloth/Fiber. The production assembly and procurement costs for the cleaner are 420.75 and 11529.29, respectively.

Since the parts #12 mesh filter, #16 upper filter and #20 rubber outer flame of fan are made of Cloth/Fiber and Rubber, these parts have recycling rate of 0 [%] due to their material types. Therefore, it requires for them to change alternative materials environmentally friendly and economically, because these parts impact on environmental loads greatly in terms of material circulation. Also, the parts #9 left and #10 right bodies, which are 1st and 2nd heaviest parts and occupied 25% of the whole product weights of the cleaner, have huge influence for recycling of the cleaner.

Therefore, this study focusses on the parts #9 left and #10 right bodies, #12 mesh filter, #16 upper filter and #20 rubber outer flame of fan, and the addresses alternative material selection for these 5 parts to improve more environmentally friendly products, while keeping production cost including assembly and procurement costs.

Numerical experiments

Table 1 shows a part of a bill of materials with results of material selection in the case of cleaner. The 8 different types of materials such as Aluminum, Magnesium, Iron, Polypropylene, Methacrylic resin, Vinyl chloride, Glass fiber and Carbon fiber have different procurement and recycling costs and recyclable weights. They become candidate materials for selecting alternative materials.

The alternative material selection has 2 objective functions for maximizing the recyclable weights and for minimizing the production costs, and adopts goal programming to solve this bi-objective problem. Goal programming requires to set target ranges for each goal by setting tolerable and sufficient levels to achieve the solutions satisfying the goals, simultaneously. The target ranges for each goal are set as follows:
Production cost

Target range for production cost is not changed. To obtain lower production cost solutions, the sufficient production cost $TC_s = 0.00$ and the tolerable production cost $TC_o = TC_{default}$ are set.

Recyclable weights

Target range for recyclable weights is changed into 8 patterns to obtain not only optimal but also alternatives. The tolerable recyclable weights $R_s=0.00$ is set. On the other hand, the sufficient recyclable weights is changed in to 8 patterns $R_s = R_{default}$, $R_s = R_{default} \times 125\%$, $R_s = R_{default} \times 150\%$, $R_s = R_{default} \times 175\%$, $R_s = R_{default} \times 200\%$, $R_s = R_{default} \times 250\%$, $R_s = R_{default} \times 300\%$, and $R_s = R_{default} \times 350\%$.

Table 1 A part of bill of materials with results of material selection: case of cleaner

<table>
<thead>
<tr>
<th>No.</th>
<th>Material type</th>
<th>Part name</th>
<th>Total weight [g]</th>
<th>Assembly cost</th>
<th>Recycling cost</th>
<th>Recyclable weight [g]</th>
<th>Procurement cost</th>
<th>Target recyclable weight</th>
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<tr>
<td>1-12</td>
<td>Default</td>
<td>Mesh filter</td>
<td>18.45</td>
<td>18.45</td>
<td>18.41</td>
<td>0.00</td>
<td>159.50</td>
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<tr>
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<td>Mesh filter</td>
<td>27.52</td>
<td>18.45</td>
<td>15.28</td>
<td>27.53</td>
<td>5.60</td>
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</tr>
<tr>
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<td>Mesh filter</td>
<td>17.52</td>
<td>18.45</td>
<td>14.71</td>
<td>17.50</td>
<td>5.46</td>
<td>Default</td>
</tr>
<tr>
<td>4-12</td>
<td>Iron</td>
<td>Mesh filter</td>
<td>10.01</td>
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<td>16.84</td>
<td>80.90</td>
<td>5.31</td>
<td>Default</td>
</tr>
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<td>Mesh filter</td>
<td>9.07</td>
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<td>9.10</td>
<td>1.26</td>
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<tr>
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<td>Upper filter</td>
<td>13.23</td>
<td>18.45</td>
<td>17.49</td>
<td>12.20</td>
<td>3.22</td>
<td>Default</td>
</tr>
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<td>7-12</td>
<td>Vinyl chloride</td>
<td>Upper filter</td>
<td>13.23</td>
<td>18.45</td>
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<td>13.30</td>
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<td>Upper filter</td>
<td>28.23</td>
<td>18.45</td>
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<td>28.26</td>
<td>13.98</td>
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</tr>
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<td>9-12</td>
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<td>20.38</td>
<td>18.45</td>
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<td>0.00</td>
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</tr>
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<td>1-16</td>
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<td>17.49</td>
<td>12.74</td>
<td>1.59</td>
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</tr>
<tr>
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<td>27.46</td>
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<td>0.00</td>
<td>16.13</td>
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<td>22.03</td>
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<td>63.68</td>
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<td>3-20</td>
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<td>10.90</td>
<td>7.41</td>
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<td>180.48</td>
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<td>17.49</td>
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<td>17.49</td>
<td>45.69</td>
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</tbody>
</table>

Figure 1 Procurement, assembly and recycling costs and recyclable weights of only treated parts as alternative material selection

Figure 1 shows procurement, assembly and recycling costs and recyclable weights of only treated parts as alternative material selection. From the figure 1, it finds out that the assembly cost is not changed for all solutions. However, the procurement cost and recyclable weights are increased as the target range for recyclable weights becomes wider. Moreover, the recycling cost is decreased even though the recyclable weights is increased. For instance, at target range of the recyclable weights for 0~350%, the production cost is lower than one at default by -6.33 [%], even though the recyclable weights becomes higher than that at default by 872.75 [%]. Additionally, the total recycling cost is also
decreased by -30.64 [%], so that the sum of the total cost becomes lower than one at default by -14.34 [%]. Therefore, at target recyclable weights of 0~350%, the effect on alternative material selection seems to appear both assembly and disassembly systems, and the recycling cost is influenced most strongly among the assembly procurement and recycling costs.

SUMMARY AND FUTURE STUDIES

This study focused on the alternative material selection for environmentally friendly and economically assembly/disassembly systems evaluations, and applied goal programming to the alternative material selection. Future studies should take account of GHG emissions at material production stage, validate the alternative materials in terms of product design.

ACKNOWLEDGEMENTS

The authors would like to thank Ms. Yumiko Ueno, Mr. Seiichi Fujita and Hitachi Ltd. for providing the AREM and REM software. This research was partially supported by the Japan Society for the Promotion of Science (JSPS), KAKENHI, Grant-in-Aid for Scientific Research (B), JP26282082 from 2014 to 2017.

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MODELING OF MATERIAL-BASED GLOBAL SUPPLY CHAIN NETWORK WITH ASIAN FREE TRADE AGREEMENTS

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ABSTRACT

Assembly manufacturing firms pursue lower production cost and Asian emerging markets. Therefore, the manufacturing of assembly products forms global supply chain networks. The global supply chain networks are consisted of not only domestic but also overseas suppliers, factories and markets. Then, the supply chain network applies customs duty when parts and products are transported across borders from overseas countries. On the other hand, the firm must consider several treaties of customs duty such as Free Trade Agreement (FTA) and Trans-Pacific Partnership (TPP).

This study models the global supply chain network with the Asian FTAs and analyzes the influence by difference patterns of the FTAs in Asia. At first, the global supply chain network in consideration of customs duty is modeled based on previous studies. Next, the model is formulated with integer programming. When numerical experiments, this study uses a bill of materials which have sizes and the weights of each part. Then, the bill of materials are made by 3D-CAD and an industry census. After that, numerical experiments are conducted, the results are discussed in terms of material types and costs for the parts.

Keywords: Integer programming, Trans-pacific partnership, customs duty, Bill of materials, Assembly products

INTRODUCTION

International assembly firms must continue changing to survive global competitions. Therefore, assembly firms reclaim emerging markets such as China and Malaysia in Asia, and it is essential for assembly firms to form global supply chain networks. When global supply chain networks are formed, an overseas suppliers and factories are included. Therefore, in the global supply chain network, customs duty is applied for international transportation of parts and products. Moreover, manufacturing firms in each country must consider Free Trade Agreement (FTA) including Trans-Pacific Partnership (TPP) to eliminate or to reduce customs duty costs among target countries. Cohens et al. (1989) [1] reported a basic framework for supply chain network design. Hosoda et al. (2016) [2] modeled global supply chain network with the combination of existing tariffs. Bruce et al. (1995) [3] and Panagiotis et al. (2007) [4] modeled global supply chain network with customs duty. Though assembly products are consisted of different parts and materials, these previous studies did not analyze using a bill of materials (BOM) which have sizes and...
weights of each part. Urata et al. (2016) [4] proposed a global supply chain network design with material-based CO₂ emissions. However, customs duty was not considered.

This study models the global supply chain network with the customs duty and Asian FTAs and analyzes the influence by difference patterns of the FTAs in Asia. At first, the global supply chain network in consideration of customs duty is modeled based on previous studies [5] [6]. Next, the model is formulated with integer programming [7]. Additionally, the bill of materials, which have parts lists including the costs, the sizes and the weights of the parts, are prepared by 3D-CAD and an industry census. Finally, numerical experiments are conducted, and after that, the results are discussed in terms of material types and costs for each part.

**MODELING AND FORMULATION OF GLOBAL SUPPLY CHAIN NETWORK WITH CUSTOMS DUTY**

Figure 1 Model of global supply chain with customs duty

This study models a global supply chain network with the customs duty for the assembly products based on [5] [6] as shown in Figure 1. The filled areas show the territories of each country. First of all, part \( j \) is produced by supplier \( l \). The purchased part \( j \) provided by supplier \( l \) is transported to factory \( a \). Each product consisting of \( n_j \) parts is assembled at factory \( a \), and after that, they are transported to market \( b \). When international transportations of the parts takes place between suppliers and factories, customs duty is applied.

Notations used in this study are set as follows:

i) **Sets**
- \( L \) : Set of suppliers
- \( F \) : Set of factories
- \( MA \) : Set of markets
- \( J \) : Set of parts

ii) **Index**
- \( l \) : Index of suppliers
- \( a \) : Index of factories
- \( b \) : Index of markets
- \( j \) : Index of parts

iii) **Decision variables**
- \( f_{la} \) : Number of parts transported from supplier \( l \) to factory \( a \)
- \( f_{ab} \) : Number of product transportation from factory \( a \) to market \( b \)
- \( z_{ab} \) : 1, if the route between factory \( a \) and market \( b \) is opened
- \( 0, \) otherwise
- \( u_a \) : 1, fixed opening cost at factory \( a \)
- \( 0, \) otherwise

iv) **Parameters**
- \( LC_{la} \) : Transportation cost of parts from supplier \( l \) to factory \( a \)
Formulation of the Problem

The objective function is minimize the sum of the transportation, procurement, customs duty and the fixed opening routes/factories costs in Eq. (1).

The unit transportation cost $LC_{la}$ is obtained by multiplying the distance $d_{la}$ between supplier $l$ and factory $a$ by transportation cost coefficient $\alpha_j$ as shown in Eq. (2). Similar to Eq. (2), the unit transportation cost $LC_{ab}$ is also multiplied by the distance $d_{ab}$ between factory $a$ and market $b$ by the cost coefficient of products transportation is $\alpha_p$ in Eq. (3). The unit customs duty $TAX1$ is obtained by multiplying the procurement cost of part $j$ supplied from supplier $l$ by a tax rate of the parts transportation from supplier $l$ to factory $a$ as shown in Eq. (4). The unit customs duty $TAX2$ is also obtained by multiplying the manufacturing cost of product at factory $a$ by a tax rate of the product transportation from factory $a$ to market $b$ as shown in Eq. (5).

Eq. (6) ensures that the demand of each market is satisfied by the open factory. Eq. (7) means that all the parts are met from the assigned suppliers. Respective Eqs. (8) and (9) ensure that the products are shipped by the opened route or factory only. Eqs. (10) and (11) enforces the non-negativity and binary restriction.

Objective function:

$$
\sum_{l \in L} \sum_{a \in F} \sum_{j \in J} \left( LC_{la} + PC_{lj} + TAX1 \right) f_{lj} + \sum_{a \in F} \sum_{b \in M} \left( LC_{ab} + MC_{a} + TAX2 \right) f_{ab} + \sum_{a \in F} \sum_{b \in M} OC_{ab} z_{ab} + \sum_{a \in F} FC_{a} u_{a} \rightarrow \text{min}
$$

Constraints:

$$
LC_{la} = d_{la} \times \alpha_j
$$

$$
LC_{ab} = d_{ab} \times \alpha_p
$$

$$
TAX1 = PC_{lj} \times \delta(l,a)
$$
Example Problem
In order to solve the mixed integer programing (MIP) problem formulated with Eqs. (1) – (11), this study prepares a global supply chain problem using a cleaner CAD model [8] [9]. The assumptions of the example problem are as follows:

- As a global supply chain problem, China and Japan are chosen because their gross domestic products (GDPs) are one of the highest countries in the world as well as United States.
- The demand city for the final assembly products is set to Tokyo, and 1,000 units of product are transported to Tokyo.
- The production locations and distances for the suppliers and the factories are prepared from cities in Japan, China and Malaysia in [5].
- The motor is always procured from China as well as [5] because the procurement cost of the motor is expensive (about 95% of total part procurement cost).

Here, two scenarios for the Asian FTA are prepared.

- **Scenario A: FTA is not applicable.**
  When the international transportation of part and product, this scenario sets customs duty rate \( \delta(l,a) \) and \( \delta(a,b) \), respectively.

- **Scenario B: FTA is applicable.**
  This scenario sets a FTA between Japan and Malaysia. When mutual international transportations between Japan and Malaysia, this scenario sets that the customs duty rate becomes 0% on mutual international transportation between Japan and Malaysia.

The solution and related results are calculated on a personal computer with Windows 7, Intel® CoreTM I7-2600 CPU operating at 3.40GHz, and a commercially available optimization solver, Numerical Optimizer provided with NTT DATA Mathematical Systems Inc. [10].

**REDESIGN PROBLEM WITH RISING PROCUREMENT PRICES**
It is often expensive to open a new factory overseas. This study treats a redesign problem, where a factory is already in Japan, and a relocation for factory’s overseas is considered. It is assumed that the factory opening cost \( FC_a \) in Japan is set as 0. The candidate sites for a new factory are China and Malaysia, and the factory opening costs \( FC_a \) in China and Malaysia are set to 5,000 US$ and 5,400 US$, respectively. On the other hand, the recent world business fluctuations affect a global supply chain network. For example, Chinese commodity prices are increased and the Chinese procurement cost may increase in the past decade. Furthermore, it is expected that suppliers are changed by increasing the procurement cost ratio. Therefore, this study simulates two cases with different Chinese parts procurement cost with...
increments by 15% and 30% for selecting economic suppliers. In this study, the procurement costs for Japanese and Malaysian parts are not changed.

Table 1 shows the supplier and factory selection result in the case of Chinese parts procurement cost increase by 15% and 30%. The baseline is prepared when the part and product custom duty rate is 20% and the Chinese parts procurement cost does not increase. From table 1, when the Chinese parts procurement cost increases by 15%, the total cost increases by 1.1% from the baseline. Simultaneously, the total cost increased by 1.7% from the baseline when Chinese parts procurement cost increase for 30%. It is found that there are supplier selection changes from the baseline in the both cases. In the case of procurement cost increment by 15%, suppliers for six parts (#9 Left body, #10 Right body, #12 Mesh filter, #14 Dust case, #16 Upper filter, #23 Fan) are changed from the Chinese to the Malaysian supplier. These

Table 1 Supplier and factory select results with increasing Chinese parts procurement cost

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Table 2 Total cost and details with increasing Chinese parts procurement cost

Table 2 shows the supplier and factory selection result in the case of Chinese parts procurement cost increase by 15% and 30%. The baseline is prepared when the part and product custom duty rate is 20% and the Chinese parts procurement cost does not increase. From table 1, when the Chinese parts procurement cost increases by 15%, the total cost increases by 1.1% from the baseline. Simultaneously, the total cost increased by 1.7% from the baseline when Chinese parts procurement cost increase for 30%. It is found that there are supplier selection changes from the baseline in the both cases. In the case of procurement cost increment by 15%, suppliers for six parts (#9 Left body, #10 Right body, #12 Mesh filter, #14 Dust case, #16 Upper filter, #23 Fan) are changed from the Chinese to the Malaysian supplier. These
parts procurement costs are highest in all parts of the cleaner. As Chinese parts procurement costs increase, expensive parts will be affected by comparing to the other parts. One of the reasons is that customs duty of parts is based on procurement cost. Therefore, customs duty is also high when Chinese parts procurement cost increases.

On the other hand, supplier for two parts (#6 Right handle, #18 Protection cap) are changed from the Chinese to the Japanese supplier. These parts procurement costs are lowest in all parts of the cleaner. In the case of lower cost parts, the transportation cost of parts occupies a higher rate in the total cost for the procurement of these parts. Therefore, suppliers which are close to the factory are selected when Chinese parts procurement cost increases.

**SUMMARY AND FUTURE STUDIES**

This study modeled the global study chain network with customs duty and Asian FTA, and analyzed the influence by difference patterns of the FTAs in Asia. Future work should expand and adopt the method to multi-objective problem in terms of not only the total cost but also CO$_2$ saving rate.

**ACKNOWLEDGEMENTS**

This research was partially supported by the Japan Society for the Promotion of Science (JSPS), KAKENHI, Grant-in-Aid for Scientific Research (C), 16K01262 from 2014 to 2016.

**REFERENCES**


MULTI-OBJECTIVE APPROACH FOR CLOSED-LOOP SUPPLY CHAIN WITH STOCHASTIC PRODUCT RETURNS

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ABSTRACT

This research focuses on the relation between manufacturing schedule and remanufacturing schedule. In recent years, the activity which reduces environmental impacts, such as recycling and reuse, is increasing. To design the closed-loop supply chain in consideration of recycling or reuse is needed also in order to construct social responsibility and competitive superiority. However, in order to establish supply chains for sustainability, it is necessary to consider into not only the environment but also economic efficiency. Many research on the closed-loop supply chain in consideration of economic efficiency is performed from various viewpoints. Some paper discussed about the influence of economic ordering quantity under the economic environment with the ordering cost and inventory holding cost for collected products under dynamic environment. However, in their model, recovered products are preferentially used from a viewpoint of reduction of environmental factors, and demand and returns are independent. The aim of this study is to perform multi-object evaluation for a closed loop supply chain. First, we assume that the arrival interval of return inward follows logarithmic normal distribution, and demand and recovered product are associated using this return model. In our model, multi-objective approach is considered to formulate and solve this multi-criteria. Finally, the influence which the scheduling of manufacturing and remanufacturing has on multi-criteria is analyzed.

Keywords: Manufacturing, Remanufacturing, Multi-objective, Production scheduling, Dynamic Environment
INTRODUCTION

In recent years, the activity which reduces environmental impacts, such as recycling and reuse, is increasing. To design the closed-loop supply chain in consideration of recycling or reuse is needed also in order to construct social responsibility and competitive superiority. However, in order to establish closed-loop supply chains for sustainability, it is necessary to consider into not only the environmental factor but also economic efficiency. In other words, the sustainability of a closed-loop supply chain should be evaluated from three sides of environment, society, and economy. Some countries have passed laws and regulations subsidizing and supporting all possible options of product recovery. Consequently, product recovery has become a profitable business option. However, it is difficult to satisfy all these sides simultaneously [1, 2].

Research on the closed-loop supply chain is performed from various viewpoints [3-6]. In general, design models of closed-loop supply chains can be classified according to two categories: deterministic and stochastic [7-17]. In many studies, the variation of return and demand in a stationary state was treated in closed-loop supply chain models. Some of references that deal with stochastic closed-loop supply chains are available in the literature [13-17]. Although these papers make valuable contributions to the literature, they make a number of assumptions, including the independence between demands and returns for the purpose of tractability. Moreover, Mitra [6] discussed about the influence of economic ordering quantity under the economic environment with the ordering cost and inventory holding cost for collected products under static environment and dynamic environment. However, in their model, recovered products are preferentially used from a viewpoint of reduction of environmental factors, and demand and returns are independent.

The aim of this study is to perform multi-object evaluation for a closed loop supply chain. First, we assume that the arrival interval of return inward follows the logarithmic normal distribution [18]. Next, we design basic models for understanding the behavior of a closed-loop supply chain with stochastic product returns in a finite horizon and investigate the influence on the cost and environmental factors of the different choices in management. Third, multi-objective approach is considered to formulate and solve this multi-criteria. Finally, the influence which the scheduling of manufacturing and remanufacturing has on multi-criteria is analyzed.

MODEL

In this study, a closed-loop supply chain model is constructed, showing how a collected amount of used products is affected by past demand. When product lifetimes follow a random variable, we investigate changes in the amount collected in each period.

Rai and Singh [18] showed the relation of the mileage of an automobile and its downtime applied to a logarithmic normal distribution. Since the data of various users is included in this distribution, such as users who hardly use an automobile and users who use an automobile daily, the lifetime of a product differs among users. When comparing the real distribution with various statistical distributions, they showed that real distribution was in agreement with a logarithmic normal distribution. In this study, we assume that the
lifetime of a product follows a logarithmic normal distribution and that it compares with the case where exponential distribution is used.

Figure 1 shows the arrival process of the returned products used in this study. The demand of period $t$, $dt$ follows a Poisson distribution at an average rate of $\mu$. The products
sold at t period are collected by the collection agency after their lifetimes. In order easily to understand this, it is assumed that all the products are collected, and customer returns and end-of-life returns are distinguished with the probability $r$. Collection time of the $k$-th product sold at period $t$ as follows:

$$C(t, k) = t + L(t, k) \quad (k=1,..., d_t) \quad (1)$$

These products sold at $t$ period are returned after different lifetimes $L(t, k)$. A remanufacturing of a product will be performed if the collected product is part of customer returns. The recovery lead-time $m$ is required for remanufacturing. The collected product can be sold again at period $s$.

$$s = [C(t, k)+m]_+ \quad (2)$$

where $[ ]_+$ is defined as a symbol showing a value obtained by rounding up to the whole number. $y(t, k)$ is an indicator function, which shows 1 whether the $k$-th product of a period $t$ becomes a customer return.

$$y(t, k) = \begin{cases} 1, & R \leq r \\ 0, & otherwise \end{cases} \quad (3)$$

$x(t, k, t')$ is an indicator function, which shows whether the $k$-th product at period $t$ can sell at period $t'$.

$$x(t, k, t') = \begin{cases} y(t, k), & t' = s \\ 0, & otherwise \end{cases} \quad (4)$$

As mentioned above, the number of recovered products at period $t$ is denoted by $N(t)$.

$$N(t) = \sum_{i=1}^{t-1} \sum_{j=1}^{d_i} x(i, j, t) \quad (5)$$

In this model, recovered products are as good as new products, and all products have the same quality as a new product. That is, all the collected returned products have the possibility of being reproduced again. $l$ shows the period when the $k$-th product at period $t$ are collected.

$$l = [C(t, k)]_+ \quad (6)$$

$z(t, k, t')$ is an indicator function which shows whether the $k$-th product at period $t$ becomes customer returned products at period $t'$. 

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Northeast Decision Sciences Institute 2017 Annual Conference
The number of customer returned products at period $t$ is denoted by $M(t)$.

$$M(t) = \sum_{i=1}^{t-1} \sum_{j=1}^{d_i} z(i, j, t)$$

And, the number of life-of-time customer returned products at period $t$ is denoted by $W(t)$.

$$W(t) = \sum_{i=1}^{t-1} \sum_{j=1}^{d_i} z(i, j, t)$$

THE TIME VARIATION OF COLLECTED PRODUCTS

Figure 2 shows the image of collection time, disposal time, and resale time of a product sold at period $t$. The demand of period $t$ is 10. The blue line shows the period during which the customer is using the product. The orange line shows the recovery lead-time of the collected product. The yellow line shows the period during which the customer is using the resale. As for products 1, 2, 3, 5, 7, 8, and 10, disposal was determined as the collection time $L(t, k)$. As for products 4, 6, and 9, remanufacturing is performed after a collection and these products are resold to the latest period after they are reproduced.
THE TIME VARIATION OF CUSTOMER RETURNED PRODUCTS

Figures 3 show the distribution of the recovered products at $t = 30$. The lifetime $L(t, k)$ follow the logarithmic normal distribution of a parameter $(1.0459, 0.3246)$. Collected products are reproduced with the probability $r$ over the lifetime. In this study, the simulation of 50 periods was performed 1000 times and the distribution of a collected product and of recovered products at $t = 30$ were calculated. Blue line shows the case of which recovery lead-time $m$ is 0. In this case, the distribution of customer-returned products and recovered products is the same. The distribution of customer-returned products thus follows a normal distribution. Red line shows the result if recovered lead-time is 5. If they have recovery lead-time, the recovered products follow binominal distribution. Gray line shows the distribution of recovered products when demand follows the Poisson distribution of an average of 10. The distribution of the recovered products follows a binominal distribution also in this case.

![Figure 3: Distribution of the recovery products](image)

PRODUCTION PLANNING OF A NEW PRODUCT AND A RECOVERY PRODUCT

In order to investigate the distribution of recovery product, a numerical experiment was performed. The lifetime $L(t, k)$ follow the logarithmic normal distribution of an average 3, standard deviation 1. It has a close relation with probability $r$ and required quality. So, we set 11 values of $r$, $(0.0, 0.1, \ldots, 1.0)$. Demand follows an average of 10 Poisson distribution. The simulation of 50 periods was performed 1000 times. In our model, we can only control the production planning of new product. Therefore, we make production planning using a scenario and two cases ($m=0$ or $m=2$).
Figure 4 and 5 shows the demands, the amount of new products and recovered products. Figure 4 and 5 show the amount when recovery lead-time $m$ is 0 and 2, respectively. If demand fluctuates, the variation in the new products becomes large. When stabilizing the production of new products, the amount of recovered products is also relatively stable. On the other hand, if recovered products are used preferentially and shortage are replenished with new products, the amount of return products become variable.

![Graph Figure 4](image)

**Figure 4** The amount of the demands, new products and recovered products ($m=0$)

![Graph Figure 5](image)

**Figure 5** The amount of the demands, new products and recovered products ($m=2$)
Figure 6 shows the relationship between recovered product and new product when demand fluctuates. Blue line shows the case where a new product is stably produced, and the red line shows the case where the recovered product is used preferentially. Generally, stable production is desired in the production process in order to increase the operation rate of facilities. On the other hand, by circulating return products to the market, it is possible to reduce the amount of new products with less recovered products.

![Figure 6](image)

**Figure 6** Relation of a recovered product and new products

**SUMMARY**

In this study, the time variation of return products in a closed-loop supply chain was investigated. The recovered product is distributed normally or binomially. Moreover, as a result of making production plans using these distributions, when recycling rate is low or recovery lead-time exist, production planning fluctuates greatly. Changes of production plan of new product may not be desirable for companies. However, changes in the production plan of new product may be able to efficiently reduce future production of new products.

**ACKNOWLEDGMENTS**

This research was partially supported by the Japan Society for the Promotion of Science (JSPS), KAKENHI, Grant-in-Aid for Scientific Research (B) JP26282082, and Grant-in-Aid for Scientific Research (C) JP16K01262.
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PERFORMANCE EVALUATION OF A DISASSEMBLY LINE WITH PREVENTIVE MAINTENANCE

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There has been a lot of talk about sustainable manufacturing as of late [1]. One of the pillars of sustainability has to do with environmentally conscious manufacturing (ECM). ECM has been a subject of interest during the recent past. There has been an increasing awareness in consequences of inefficient uses of natural resources and increasing amount of wastes among its cohorts, such as government units, manufacturers and consumers. Of the many important aspects of ECM, product recovery plays a major part in separating reusable components and materials from end-of-life products and transporting them to remanufacturing and recycling industries. This is a way to reduce wastes and use natural resources effectively. The practice consists of collection of end-of-life products, disassembly, cleaning, inspecting, and categorizing of recovered components and materials. A key element of successful product recovery is selective disassembly. Selective disassembly helps in increasing the recovery rate of valuable components and materials that are highly demanded and in minimizing costs of removing unwanted components. Among several disassembly settings that are employed in selective disassembly, disassembly line is one of the most commonly used settings. It is also considered one of the most suitable and effective ways to disassemble products in large quantity. Disassembly line consists of a series of workstations working sequentially separating target components from the EOL products and subassemblies. A disassembly line faces numerous uncertainties and difficulties that are not present in an assembly line. These include arrival pattern of EOL products and demand for components, and unconventional fluctuation in inventory due to the disparity in yields and demands.

In an assembly line scenario, when there is a need to perform maintenance to a server, blocking and starvation are common problems. However, pattern of material flows in assembly line is deterministic and straightforward. There usually is a single product demand at the end of the line. That is, the exact destination and amount of material being transferred is known. Hence, planning in advance can help managing blocking and starvation. On the other hand, disassembly line faces two major obstacles. One obstacle occurs due to the uncertainty in the arrivals of 3 demand and supply. EOL products usually arrive in unpredictable conditions. They may also
comprise of unknown number of components. These can create unpredictable flows of components in the disassembly line. Demands can also create further complications because they may arrive at varying levels along the line. This causes irregular variations in the number of components being supplied and demanded. Another obstacle occurs due to the nature of the disassembly process. The disassembly process often delivers two categories of components, viz. target component and residual component. The target component is usually in high demand while the residual component is in low demand or not demanded.

Similar to an assembly line setting, there are two types of control mechanisms in a disassembly line setting, viz., the push system and the pull system. A push system is easy to implement but is generally not efficient in the disassembly environment as it tends to generate large amounts of inventories. However, this may be beneficial during preventive maintenance. A pull system, on the other hand, operates efficiently and generates less amounts of inventory. Yet, with the occurrence of interruptions, this can be problematic. Most production control tools that implement pull mechanisms in the assembly line settings are not practical for the disassembly line settings. Moreover, some disassembled residuals have short shelf-lives. Some incur high storage cost especially if the amount of disassembled residuals is large.

In this paper, we demonstrate how a pull system, such as a Kanban mechanism, could be modified and implemented efficiently in disassembly line settings. We study the effects of interruption caused by preventive maintenance on the performance of a disassembly line. To that end we present a methodology to implement a kanban system in a disassembly line setting with the occurrence of preventive maintenance. We consider a case example to illustrate the implementation of the methodology and obtain results using simulation. We compare the performance of the pull system with that of the push system.

References


Pricing Models of New and Remanufactured Products in Multiple Product Generation Lines

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ABSTRACT

Many companies have started producing remanufactured products to take the responsibility of environmentally conscious manufacturing and product recovery. To promote the remanufactured products, marketing-related issues are necessary to be focused on, and pricing policy is one of the key factors for marketing and revenue. High technology product, such as the smartphone in our case, requires intensive generation update, which causes to the obsolescence of early generation and creates potential competition between the new products belonging to the old generation and the remanufactured products belonging to the latest generation. This paper proposes to build pricing models based on the time-depended diffusion demand function with the objective of maximizing the profit of each party and the joint profit of the supply chain. Two systems are studied. The first one consists of a retailer and a manufacturer, while the second one concludes the third-party remanufacturer. The constraints on the quantity of new and remanufactured products are considered.

Keywords: Pricing, Remanufacturing, Generation, Competition

1. INTRODUCTION

Environmentally conscious manufacturing and product recovery (ECMPRO) is becoming a responsibility of the manufacturers as a result of take-back legislations, customers’ awareness of green products, and economics [1]. According to the two surveys in the year 1999 [2] and 2010 [3], scientists have started to pay attention to environmentally conscious design and production, material recycling and remanufacturing. Lately, researchers have extended these ideas into reverse and closed-loop supply chains. These include marketing-related issues to promote remanufactured products.
Pricing policy is a key factor for marketing remanufactured products which differs from product to product. High technology product, such as a smartphone, has a short life cycle, because customers constantly demand new design and latest technology products. Technology companies often release new versions of products periodically which lead to coexistence of products with multiple generations. At the same time, third party manufacturers start remanufacturing and introducing products belonging to the latest generation into the market. They capture market share and attract middle-level customers who prefer these over the new products belonging to the earlier generation. How to balance the profit of original equipment manufacturer (OEM), retailer and third party manufacturer (TPM) with the best pricing policy is the subject of this study.

2. LITERATURE REVIEW

The smartphones have short lifecycle and intensive technology innovation. Because of the existing of products in different generations, the previous researcher did amount of work on developing price models for new products in multi-generation lines. Firstly, Bass model [4] is built in the earlier year based on a diffusion model. Then Norton and Bass [5] applied the theory to the substitution for generations of high-technology products. To maintain the market share for the products in all generations, introduction strategy is always sensitive. Arslan, Kachani and Shmatov [6] Rubel [7] and Seref, Carrillo and Yenipazarli [8] write papers to find the optimal product launch time as well as the pricing policies. Some researchers consider the side of customers. Zhou, Zhang, Gou, Liang [9] analyzed three launching strategies for a fashion firm with the consideration of consumers’ satiation effect. Liang, Cakanyildirim, and Sethi [10] take the customer segmentations and generation innovation into account. Besides, coexisting of multiple generations also causes to the internal competition. Plenty of previous researchers pointed out and analyzed the effect of the generation cannibalization. Three of the papers we reviewed conduct agent decision rules for dynamic pricing modeling [11] [7] [12]

High technology products have the nature of updating the product version intensively, while the customers have the nature of obtaining new product belonging to the latest innovation. Remanufacturing operations come out to satisfy the middle level technology-savvy customers. Gan, Pujawan,Suparno and Widodo [13] provide an example of such the product with a time-dependent demand model in two phases under a monopoly environment with unlimited used cores. Different from Gan et al., Ferrer and Swaminathan [14], Chen and Chang [15] take the availability of cores into account. Ferrer and Swaminathan build a price-based demand model. Chen and Chang [15] build a model in multiple periods setting. Additionally, Vadde, Kamarthi and Gupta [16] focused on the pricing strategies under product’s gradual and sudden obsolescence. In this paper, we will focus on remanufactured products in a multi-generation production line.

3. PROBLEM STATEMENT

Two types of products are analyzed. TYPE1 product is a new product belonging to the previous generation. TYPE2 product is a refurbished product belonging to the latest generation. TYPE2 products are available several months after the new product with the new generation is released, while TYPE1 products are still available in the market. TYPE1 and TYPE2 products share the middle-level market, separate from the market of new latest generation product. Consumers in middle level are classified as quality-conscious and technology-savvy.
assumes that quality-conscious customers will buy the TYPE1 product and those who are technology-savvy will buy TYPE2. They never transfer no matter how the prices change. The prices are demand-dependent. The demand functions are linearly related to price, and follow a diffusion curve with two different phases [13] [17].

Figure 1 shows the demand curves of two types of products, which contains two product generations. The part above line represents the demand of the new products, and the part below line represents the demand of the remanufactured ones. We assume that TYPE1 products will not be phased out, while TYPE2 products will be phased out of the market if the remanufactured latest generation product is available. $D_{ni1}(t)$ means the demand of the new product of Generation $i$ in the increase phase; $D_{ni2}(t)$ means the demand of the new product of Generation $i$ in the decrease phase. When the new product belonging to Generation $i+1$ is launched, Generation $i$ will go to the decrease phase. $D_{ri}(t)$ represents the remanufactured product of Generation $i$ in the increase phase. The market requires no early generation remanufactured product, therefore there is no decrease phase for the remanufactured products.

![Demand curve of TYPE1 and TYPE2 products](image)

The demand functions are as follows:

$$D_{ni1}(t) = \frac{U}{1 + ke^{-\lambda t}} \quad t_0 \leq t < t_2$$
$$D_{ni2}(t) = \frac{\lambda U}{U(t_4 - t_2) + \delta} \quad t_2 \leq t \leq t_4$$
$$D_{ri1}(t) = \frac{V}{1 + ke^{-\eta t}} \quad t_1 \leq t \leq t_2$$
$$D_{ri2}(t) = \frac{\eta V}{1 + ke^{-\eta(t_4 - t_2)}} \quad t_2 \leq t \leq t_3$$
$$D_{ri3}(t) = \frac{\tau V}{1 + ke^{-\eta(t_4 - t_3)}} \quad t_3 \leq t \leq t_4$$

Where

$$k = \frac{U}{D_0} - 1; \quad \delta = 1 + ke^{-\lambda\tau}; \quad h = V/D_0 - 1; \quad \tau = 1 + ke^{-\eta(t_3 - t_1)}$$

**Notations**

- **$U$** = Maximum possible demand for new product
- **$\lambda$** = Speed of demand change in a time function for new product
- **$D_0$** = Demand at the beginning of the product lifecycle when $t=0$
- **$V$** = Maximum possible demand for remanufactured product
- **$\eta$** = Speed of demand change in a time function for remanufactured product
- **$D_{ri}$** = Demand at the beginning of the product lifecycle where $t=t_1$ and $t=t_3$
Two systems are analyzed. The first one is a monopoly system, which has two players: OEM and retailer. In the second system, TPM is in. They take over all the responsibility for remanufacturing and selling remanufactured products. Figure 2 and figure 3 show the monopoly system and the system with TPM respectively.

![Figure 2: Monopoly system](image1)

![Figure 3: The system with the individual third party manufacturer](image2)

In both of the two systems, the objective is to find optimal prices to maximize the profit through $t_0$ to $t_4$, in two production generations, and analyze how to price different types of products in different time. The prices are linear.

4. MODELS

Suppose that a company designs a multi-generation production line. Let $P_m$ represent the upper bound of retailer price of new product of the Generation $i$ in increase phase, if Generation $i$ is the latest product in the market. $i=1, 2, 3 \ldots k$. Let $P_{ni+1,1}$ represent the upper bound of retailer price of new product belonging to Generation $i$ in decrease phase. For the maximum price of remanufactured products, $P_{ni1}$ represents the upper bound of remanufactured product of
Generation i if the new Generation i+1 has not released; \( P_{n+2} \) is assumed the upper bound of remanufactured product of Generation i when Generation i+1 is released.

4.1 Monopoly system

4.1.1 Retailer’s Model

In this model, the wholesale price is determined. The retailer optimizes the profit accordingly. The results will show how to price different products in specific time is more beneficial to the retailer only.

\[
\bar{\pi}(N) = \int_{t_0}^{t_2} \frac{V}{1 + ke^{-\lambda t}} \left(1 - \frac{P_{n+1}}{P_m}\right) \left(P_{n+1} - P_{nw}\right) dt + \int_{t_2}^{t_4} \frac{V}{1 + ke^{-\lambda t}} \left(1 - \frac{P_{n+2}}{P_{n+1}}\right) \left(P_{n+2} - P_{nw}\right) dt
\]

\[
\bar{\pi}(Remanufactured) = \int_{t_1}^{t_3} \frac{U}{1 + he^{-\eta t}} \left(1 - \frac{P_{r+1}}{P_{r+1}}\right) \left(P_{r+1} - P_{rw}\right) dt + \int_{t_3}^{t_5} \frac{U}{1 + he^{-\eta t}} \left(1 - \frac{P_{r+2}}{P_{r+1}}\right) \left(P_{r+2} - P_{rw}\right) dt
\]

Max \( \Pi_R = \Pi_R (New) + \Pi_R (Remanufactured) \)

\[
= d_1 \left(1 - \frac{P_{n+1}}{P_m}\right) (P_{n+1} - P_{nw}) + d_2 \left(1 - \frac{P_{n+2}}{P_{n+1}}\right) (P_{n+2} - P_{nw})
\]

\[
+ d_3 \left(1 - \frac{P_{r+1}}{P_{r+1}}\right) (P_{r+1} - P_{rw}) + d_4 \left(1 - \frac{P_{r+2}}{P_{r+1}}\right) (P_{r+2} - P_{rw})
\]

Where

\[
d_1 = \frac{1}{\lambda} \ln \left(\frac{V}{(1 + ke^{-\lambda t})}\right) - d_1
\]

\[
d_2 = \frac{1}{\lambda} \ln \left(\frac{V}{(1 + he^{-\eta t})}\right) - d_2
\]

\[
d_3 = \frac{1}{\eta} \ln \left(\frac{V}{(1 + he^{-\eta t})}\right) - d_3
\]

In the model, \( d_1, d_2, d_3, d_4, d_5, d_6 \geq 0 \). T is the quantity of the products in Generation i, \( \beta \) is remanufacturing rate.

Decision variables: \( P_{n1}, P_{n2}, P_{n21}, P_{n11}, P_{r11}, P_{r12}, P_{r21} \).

Parameters: \( P_{nw}, P_{rw}, P_m, d_1, d_2, d_3, d_4, d_5, d_6, U, V \).

Constraints: \( P_{n1} \leq P_m, P_{n2} \leq P_m, P_{n21} \leq P_{n2}, P_{r11} \leq P_{n1}, P_{r12} \leq P_{r12}, P_{r21} \leq P_{n21}, P_{n1} \leq P_{n1} \).

4.1.2 Manufacturer’s model

We assume that manufacturer is the Stackelberg leader. The retailer would have been in lower bargaining position. Because the problem is under a monopoly setting, the manufacturer in the system does not have any competition and can control the revenue and cost. Therefore, the result
of the model provides the idea how to adapt to the demand curve with price. $\theta$ is exponent of the return rate power functions. $\gamma$ is constant coefficient of the return rate.

$$\text{Max } \Pi_M = \Pi_M (\text{New}) + \Pi_M (\text{Remanufactured})$$

$$= [d_1* \left(1 - \frac{P_{n1}}{P_m}\right) + d_2* \left(1 - \frac{P_{n12}}{P_{n21}}\right) + d_3* \left(1 - \frac{P_{n21}}{P_m}\right)] \cdot (P_{nw} - Cn)$$

$$+ [d_4* \left(1 - \frac{P_{r11}}{P_{n11}}\right) + d_5* \left(1 - \frac{P_{r12}}{P_{n21}}\right) + d_6* \left(1 - \frac{P_{r21}}{P_{n21}}\right)] \cdot (P_{rw} - Cr - \theta + 1)$$

$$\gamma \cdot (d_4* \left(1 - \frac{P_{r11}}{P_{n11}}\right) + d_5* \left(1 - \frac{P_{r12}}{P_{n21}}\right) + d_6* \left(1 - \frac{P_{r21}}{P_{n21}}\right))^\theta)$$

Decision Variables: $P_{nw}$, $P_{rw}$.

Parameters: $P_m$, $d_1$, $d_2$, $d_3$, $d_4$, $d_5$, $d_6$, $C_n$, $C_r$, $\theta$, $\gamma$.

Constraints: $P_{n11} \leq P_m$, $P_{n21} \leq P_{n11}$, $P_{r11} \leq P_{n11}$, $P_{r12} \leq P_{n21}$, $P_{r21} \leq P_{n21}$, $P_{n12} \leq P_{n11}$, $C_n \leq P_{nw}$, $C_r \leq P_{rw}$.

4.1.3 Joint profit model

As the retailer would have been in lower bargaining position and decides the retailer price accordingly, the joint profit model is important for the survival of retailers, while the manufacturer can share revenue with the retailer.

$$\text{Max } \Pi_J = \Pi_R + \Pi_M$$

$$= d_1* \left(1 - \frac{P_{n1}}{P_m}\right) \cdot (P_{n1} - P_{nw}) + d_2* \left(1 - \frac{P_{n12}}{P_{n21}}\right) \cdot (P_{n21} - P_{nw}) + d_3* \left(1 - \frac{P_{n21}}{P_m}\right) \cdot (P_{nw} - Cn)$$

$$+ [d_4* \left(1 - \frac{P_{r11}}{P_{n11}}\right) + d_5* \left(1 - \frac{P_{r12}}{P_{n21}}\right) + d_6* \left(1 - \frac{P_{r21}}{P_{n21}}\right)] \cdot (P_{rw} - Cr)$$

$$\gamma \cdot (d_4* \left(1 - \frac{P_{r11}}{P_{n11}}\right) + d_5* \left(1 - \frac{P_{r12}}{P_{n21}}\right) + d_6* \left(1 - \frac{P_{r21}}{P_{n21}}\right))^\theta)$$

Decision Variables: $P_{nw}$, $P_{rw}$, $P_{n11}$, $P_{n12}$, $P_{n21}$, $P_{n11}$, $P_{r11}$, $P_{r12}$, $P_{r21}$.

Parameters: $P_m$, $d_1$, $d_2$, $d_3$, $d_4$, $d_5$, $d_6$, $C_n$, $C_r$, $\theta$, $\gamma$.

Constraints: $P_{n11} \leq P_m$, $P_{n21} \leq P_{n11}$, $P_{n12} \leq P_{n21}$, $P_{r11} \leq P_{n11}$, $P_{r12} \leq P_{n12}$, $P_{r21} \leq P_{n21}$, $P_{n12} \leq P_{n11}$, $C_n \leq P_{nw}$, $C_r \leq P_{rw}$.

4.2 The system with TPM

TPM takes over all the responsibility of remanufacturing. Retailer’s model and manufacturer’s model only consider the cost and the revenue of the new products.

4.2.1 Retailer’s model
Max $\Pi_R = d_1^* \left( 1 - \frac{P_{n11}}{P_m} \right) (P_{n11} - P_{nw}) + d_2^* \left( 1 - \frac{P_{n12}}{P_{m}} \right) (P_{n12} - P_{nw})$

$+ d_3^* \left( 1 - \frac{P_{n21}}{P_m} \right) * (P_{n21} - P_{nw})$

4.2.2 Manufacturer’s model

Max $\Pi_M = \left[ d_1^* \left( 1 - \frac{P_{n11}}{P_m} \right) + d_2^* \left( 1 - \frac{P_{n12}}{P_{m}} \right) + d_3^* \left( 1 - \frac{P_{n21}}{P_m} \right) \right] * (P_{nw} - C)$

4.2.3 The individual third party manufacturer model

Max $\Pi_I = d_4^* \left( 1 - \frac{P_{r11}}{P_{m}} \right) * (P_{r11} - Cr)

+ d_5^* \left( 1 - \frac{P_{r12}}{P_{m}} \right) * (P_{r12} - Cr) + d_6^* \left( 1 - \frac{P_{r21}}{P_{m}} \right) * (P_{r21} - Cr) + \left[ d_4^* \left( 1 - \frac{P_{r11}}{P_{m}} \right) + d_5^* \left( 1 - \frac{P_{r12}}{P_{m}} \right) + d_6^* \left( 1 - \frac{P_{r21}}{P_{m}} \right) \right] * \left( Prw - Cr - \frac{\theta + 1}{\theta} \gamma \left( d_1^* \left( 1 - \frac{P_{r11}}{P_{m}} \right) + d_2^* \left( 1 - \frac{P_{r12}}{P_{m}} \right) + d_3^* \left( 1 - \frac{P_{r21}}{P_{m}} \right) \right) \right)$

5. NUMERICAL EXAMPLE

The parameters are using data from numerical example in [13]. We assume $U = 1000$, $D_0 = 90$, $\lambda = [0.01, 0.05, 0.1]$ for the demand of new product; $V = 500$, $D_{ro} = 50$, $\eta = [0.01, 0.05, 0.1]$ for remanufactured product. $t_1 = t_2 = t_3 = t_4 = 1$ represent the selling horizons. Unit new product cost is combined with raw material cost and manufacturing cost, which is $C_n = 2500$. Unit remanufactured product cost concludes collecting cost and remanufacturing cost, which is $C_r = 900$ in total. Maximum price is $P_m = 12000$. Return rate parameters are $\gamma = 0.01$, and $\theta = 0.7$. Table 1 shows the results of the first system combined with a retailer and a manufacturer without the constraints of product quantity. Table 2 illustrates the result of the restriction of $d_2$ and $d_5$. Table 3 demonstrates the system with a TPM.

In system 1, the retailer’s profit optimized if the new product of later generation increases the price. The product of Generation 1, for both of the new and remanufactured ones, does not change the price even the new version is launched. The price of the remanufactured product of Generation 2 increases with the increases of the new one. The ascensional range in price is based on the value of the speed of demand change $\eta$ and $\lambda$. While in the view of the manufacturer, increasing the rate of Generation 1 when Generation 2 is available will bring more benefit, which has a conflict with the retailer. The result suggests the OEM selling more remanufactured products of the newest generation in a maximum wholesale price. With the increase of $\eta$ and $\lambda$, the higher price of all types of products in all periods, the more profit the OEM will obtain. For maximizing the joint profit, the result shows the maximal profit if the price of the new product belonging to the early generation decrease a little bit when the latest version is available; and the Generation 2 will have a higher price than Generation 1 in increase phase. With the increased value of speed change, the model suggests the lower price for the early generation and the higher price for the new generation, an especially higher price for the remanufactured product belonging to the latest generation. The most interesting finding is that the joint profit model suggests a higher wholesale price for the remanufactured products than the new products, which causes the loss of the retailer. However, it potentially indicates the more profitability of remanufactured products belonging to the latest generation.
If the availability of TYPE 2 product and the remanufactured product in the later period are considered, both of the models of the retailer and the joint profit suggest declining the price of all products in all period. And all of the three models shows the lower price of generation 1 when generation 2 is introduced.

In the system with the players of the retailer, the manufacturer and the ITM, ITM takes over all remanufacturing operations. The result of ITM model shows that if the product with the latest generation increases the price, the more benefit the remanufacturing operations will gain.

<table>
<thead>
<tr>
<th>Table 1. The results of system 1 without the constraint in availability</th>
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<tbody>
<tr>
<td><strong>Variables</strong></td>
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<tr>
<td>$P_{r1}$</td>
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<td>$P_{r2}$</td>
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<tr>
<td>$P_{m1}$</td>
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<tr>
<td>$P_{m2}$</td>
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<td>$P_{r1}$</td>
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<tr>
<td>$P_{m1}$</td>
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<td>$P_{m2}$</td>
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<tr>
<td><strong>objective value</strong></td>
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<tr>
<th>Table 2. The results of system 1 with the constraint in availability</th>
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<tbody>
<tr>
<td>**System 1 (q₂=0.01)</td>
</tr>
<tr>
<td>$P_{r1}$</td>
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<td>$P_{r2}$</td>
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<tr>
<td>$P_{m1}$</td>
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<td>$P_{m2}$</td>
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<tr>
<td>$P_{r1}$</td>
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<td>$P_{r2}$</td>
</tr>
<tr>
<td>$P_{m1}$</td>
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<tr>
<td>$P_{m2}$</td>
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<tr>
<td><strong>objective value</strong></td>
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| System 3 (q₂=0.1) | **Variables** | **Retailer** | **Manufacturer** | **ITM** |
| $P_{r1}$ | 13024 | 9819 | 11135 |
| $P_{r2}$ | 2500 | 9819 | 2500 |
| $P_{m1}$ | 13024 | 10855 | 11135 |
| $P_{m2}$ | 26707 | 9819 | 24323 |
| $P_{r1}$ | 6962 | 0 | 6245 |
| $P_{r2}$ | 900 | 9819 | 3573 |
| $P_{m1}$ | 6962 | 0 | 6245 |
| $P_{m2}$ | 13803 | 9819 | 13004 |
| **objective value** | 13,085,550 | 10,761,370 | 12,550,760 |

<table>
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<tr>
<th>Table 3. Result of system 2 with the speed of demand change (\eta,\lambda=0.01)</th>
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<tr>
<td>**System 2 (q₂=0.01)</td>
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<tr>
<td>$P_{r1}$</td>
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<td>$P_{r2}$</td>
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<td>$P_{m1}$</td>
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<td>$P_{r1}$</td>
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<td>$P_{r2}$</td>
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<td>$P_{m1}$</td>
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<td><strong>objective value</strong></td>
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6. DISCUSSION AND CONCLUSION

This study extends the model of previous work on the pricing of new and remanufactured products with the consideration of two generations period. Different systems are analyzed. In general, the models indicate the significant potential benefit of TYPE 2 product. In the future study, manufacturer’s dual channel system is necessary to study. Also, the potential reason why the refurbished product belonging to the latest generation provide more profit is worthy of excavating.
References


PRODUCTION POLICIES IN TWO-TIER SUPPLY CHAINS WITH MULTIPLE SUPPLIERS AND RETAILERS

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ABSTRACT
In this paper we study a two-tiered supply chain with multiple suppliers and retailers. Suppliers have limited capacity and stochastic yield. We propose and analyze two production policies for suppliers. Supply chain costs and service level are determined using discrete-time simulation. We identify under which conditions a policy performs better than the other one.
INTRODUCTION AND LITERATURE REVIEW

Many manufacturers have to deal with a number of issues such as yield uncertainty, demand uncertainty and production capacity. A good production policy can reduce operational costs significantly and give a company a competitive advantage against rivals. In this study we investigate the effect of production policies in a two-tier supply chain with multiple suppliers (manufacturers) and multiple retailers where suppliers are capacitated and face both demand and yield uncertainty. Using discrete time simulation we analyze the supply chain’s performance under two different production policies to gain managerial insight.

There are a number of studies on supply chains with multiple suppliers/retailers that utilize simulation. A review of multiple-supplier inventory models is available by Minner (2003). Ganeshan (1999) studies a production/distribution network with multiple suppliers, a central warehouse and multiple retailers. He provides an \((s, Q)\)-type inventory policy at both retailer and warehouse level as a heuristic solution under stochastic demand and lead time with customer service constraints. Huang and Gangopadhyay (2004) study a tree-like, four-tier supply chain (a manufacturer, two wholesalers, four distributors, and eight retailers) to measure the impact of information sharing among supply chain partners using simulation. They find that distributors and wholesalers benefit from information sharing significantly in terms of backorders and inventory holding costs, but not retailers. A four-tier supply chain (a manufacturing plant, a vendor distribution center, a retailer distribution center, a retailer store) is studied by Angulo et al. (2004) via discrete-time simulation. The study finds that sharing forecasts should be implemented first on products with increasing or decreasing mean demand rates. Abuhilal et al. (2006) simulate a three-tier supply chain (a supplier, a manufacturer and a retailer) to compare JIT and MRP strategies for a manufacturer under stationary and cyclical demand showing that JIT reduces inventory; and that information sharing between supply chain stages causes significant cost reduction when MRP strategy is used, especially with cyclical and highly variable demand. Choudry et al. (2008) study a two-tier capacitated supply chain with single manufacturer and multiple identical retailers to investigate the effect of factors such as demand variability, production availability, number of retailers, and information sharing between stages on the performance of a supply chain using simulation. They compare three different information sharing strategies via simulation and optimize the order-up-to and safety stock levels for retailers and start-up and shut-down levels for the manufacturer using response surface methodology. Chin et al. (2012) study a three-tier supply chain with a manufacturing plant, five warehouses, four clients for each warehouse; there are six different products that are made in the plant...
and sold through the warehouses. They use simulation to verify that a pull-type Theory of Constraints Supply Chain Replenishment System (TOC-SCRS) performs better than a push-type replenishment system by minimizing the bullwhip effect. Jaber and Goyal (2008) use a deterministic mathematical model to improve coordination in a three-level, centralized supply chain with multiple retailers, a manufacturer and multiple suppliers. Shaltayev et al. (2016) study the effect of several factors on average transaction cost and service level in a two-tiered perishable supply chain with multiple suppliers and multiple retailers via discrete time simulation. They find that transaction cost increases as supply variability increases; service level and average transaction costs are not significantly affected by number of suppliers and retailers. Shaltayev et al. (2016a) investigate the effect of lead time on their proposed heuristic production policy in a two-tiered supply chain with constrained supply using simulation. They observe that changes in delivery lead time do not affect the optimal parameters of the production policy for the supplier in a substantial way. Shaltayev et al. (2016b) use simulation to analyze the extent of demand variability’s effect on supply chain costs and service level when there are multiple suppliers and retailers in a two-tiered supply chain, where suppliers have limited capacity and stochastic yield. They observe that when customer demand variability is increased, cost and service level get worse for both the suppliers and retailers, except when there is no oversupply in the supply chain.

**THE MODEL**

In our model the supply chain has two tiers with \( r \) retailers and \( s \) suppliers. Each retailer tries to buy goods from its primary supplier at the beginning of each period; and each supplier has a certain number of retailers, for which the supplier serves as primary. Suppliers are capacitated and have random yields; if a supplier cannot fulfill its retailers’ demand, then the supplier distributes its available inventory amongst retailers proportionally according to each retailer’s order size. In such a case, the supplier would have no inventory remaining, and its retailers would be still in the market looking to buy the goods they demand. If the primary supplier cannot fulfill all of retailer orders, then the retailers with remaining demand will order the missing goods from one of the remaining suppliers with highest available inventory. At the beginning of the next period, retailers do not change their primary supplier from the previous period.
Figure 1. Two-Tier Supply Chain with Multiple Retailers and Multiple Suppliers.

In our model each retailer offers the same product to end customers with no price differentiation. Demand experienced by the retailers each period is normal, independent and identically distributed. Delivery of an order from a supplier to a retailer in general has a lead time $L$. Any unmet consumer demand or retailer demand is backordered. Unmet consumer or retailer demand results in a shortage cost. Any excess inventory held by the supplier or the retailer has a holding cost. We use three different delivery methods in our model. Each of these delivery options are equally fast, but they have a different cost. The selected shipping method based on the retailer’s order size. Larger orders are cheaper per product, whereas smaller orders are more expensive per product. This introduces economies of scale in the model.

The market operates in three distinct phases. In Phase-1, each supplier produces a random yield of $n$ amount of goods. Supplier’s target supply varies according to the supplier’s ending inventory. The yield is normally distributed. During Phase-1, the retailers place orders to suppliers. The order size is determined by the retailer’s pipeline inventory, ending inventory and service level. If any retailer still requires more inventory after the initial ordering phase, they may order more goods from secondary suppliers – this is if they have any goods left. In Phase-2, a random retailer with unmet demand is selected and its demand is fulfilled using the goods from the supplier that has the highest available supply. Phase-2 ends, when retailer demand is not met or suppliers run out of inventory. In Phase-3, customers purchase inventory from the retailer. After Phase-3, ending inventories for both the suppliers
and retailers are calculated. If the ending inventory for either the retailer or supplier is negative, a backorder cost is incurred; if the ending inventory is positive, a holding cost is incurred.

**PRODUCTION POLICIES**

In this paper we consider two production policies: *Yield Reduction Only* (YRO) policy and *Stop Production/Yield Reduction* (SPYR) policy. The description of the policies are as follows:

1. **Yield Reduction Only Policy (YRO):** Under YRO policy it is assumed that the retailer operates at the maximum capacity possible defined by the formula (1) above. At each time period supplier observes the ending inventory level, and adjusts production for the next time period as follows:

\[
(Average \ Supplier \ Yield)_t = (Supplier \ Production \ Capacity) - (Yield \ Reduction \ Factor) \times (EI)_{t-1}
\]

where \((EI)_{t-1}\) is a positive ending inventory in previous time period, and Yield Reduction Factor (YRF) can take the values of \{0, 0.5, 1, 1.5, 2, 2.5, 3, 3.5\}.

For example, if the supplier production capacity is 330 units per period, YRF = 0.5, and ending inventory of EI = 20 units was observed in the previous period, then average supplier yield for current time period is set to 320 units. Note that exact supplier yield for period \(t\) is still not known with certainty, as it is a random value from a normal distribution with average yield of 320 units. Formula (2) above sets the average of the yield distribution which supplier chooses after observing leftover inventory. Also note that if supplier observed a shortage in time period \((t-1)\), then YRF = 0, and average supplier yield in current time period is equal to the full supplier production capacity given by the formula (1). Under YRO policy the average supplier’s yield can theoretically be adjusted each time period.

2. **Stop Production / Yield Reduction (SPYR):** In this policy each time period a supplier is using formula (2) to adjust the average yield each period if \((EI)_{t-1}\) is less than average one period demand observed by “assigned” to him retailers, and stops the production completely for one period otherwise.
**SIMULATION DESIGN**

A simulation study was performed to investigate the effect of supply chain parameters on two performance measures: average supplier’s inventory-related cost and average retailer’s cycle service level (CSL). Cycle service level is defined as a fraction of inventory replenishment cycles when the customer demand is satisfied out of retailer’s on-hand inventory. In this research we assume that retailer and supplier do not share information, and each supplier makes production decisions aiming to minimize his cost regardless of retailers’ targeted levels of product availability.

We model customers’ demand for each retailer using a normal distribution with a mean of $\mu = 100$ units per time period. Retailer backorder cost is $10$, supplier backorder cost is $5$, retailer holding cost is $4$, supplier holding cost is $2$ (all per unit). We use three different delivery methods in our model. Each of these delivery options are equally fast, but they have a different cost ($200, $75 and $10). The selected shipping method based on the retailer’s order size. Larger orders are cheaper per product, whereas smaller orders are more expensive per product; this introduces economies of scale in the model. For each combination of parameters we ran 10,000 periods. The model was simulated using Python we use the following supply chain parameters:

1) Retailer’s demand variability ($CV_D$): For each retailer we use the coefficient of variation, $CV_D$, as a measure of demand variability observed by retailers. We use values $CV_D = 0.15, 0.3$, which are referred as low and high demand variability.

2) Supplier’s yield variability ($CV_S$): Similar to demand variability, we use values $CV_S = 0.15, 0.3$ for each supplier. We refer to these cases as low and high supply variability.

3) Retailer’s Targeted Customer Service Level ($CSL_T$): We use values of $0.8, 0.9, 0.95, 0.99$. We should point out that $CSL_T$ can be viewed as a decision variable, because a retailer chooses a cycle service level to pursue. The optimal CSL value can be inferred as a trade-off between overstocking cost $H$ and understocking cost $B$ as $CSL^* = B/(B+H)$. Since we do not consider overstocking and understocking costs in our model, we do not make any assumptions regarding which CSL value is targeted by retailers. Instead, we investigate the behavior of the two selected performance measures under different levels of targeted CSL. We assume that all retailers target same CSL, as they all face same overstocking and understocking cost. Since all retailers observe normally distributed demand with the same parameters, all retailers order the same quantity each time period.
4) Number of suppliers: We investigate cases with 2, 3 and 4 suppliers.

5) Retailer-to-supplier ratio (RSR): RSR is defined as ratio of the number of retailers to the number of suppliers. We use RSR values of 2, 3 and 4. Note that with different number of suppliers even the same RSR value results in different number of retailers in a supply chain.

6) Supply availability factor (SAF) or Oversupply: We define supply availability as ratio of total average supply to total average demand. For example, if we use three suppliers with average supply 300 units each per time period and 9 retailers facing average customers’ demand of 100 units each, SAF is equal to 1. The higher the supply availability factor value, the more inventory is provided by suppliers to meet demand. We use three values or the SAF parameter: 1.0, 1.05, 1.1. Values of 1.05 and 1.1 indicate that suppliers can provide 5 and 10 percent more units, respectively, than customers demand on average. In this paper we determine supplier production capacity using the following formula:

\[
\text{Supplier Production Capacity} = (\text{Cumulative Demand from Retailers Assigned to Supplier}) \times \text{SAF} \quad (1)
\]

where supply factor SAF \( \in \{1.0, 1.05, 1.1\} \).

RESULTS AND CONCLUSION

Our simulation results demonstrate that on average SPYR policy performs 31% better than YRO policy in terms of total supplier costs. However we have observed that YRO policy improves the service level for retailers; on average when YRO policy is used retailers achieve about 20% higher cycle service level compared to SPYR policy. Our results indicate that as oversupply decreases (i.e. average supplier’s yield is equal to the average demand observed by retailers), SPYR performs better compared to YRO in terms of average retailer’s cost, average supplier’s cost and average supply chain cost. We have also observed that as retailer-to-supplier ratio, demand and supply uncertainty increase SPYR performs better compared to YRO in terms of operational costs.


Reviewing and Proposing with Building Demand Chain

ABSTRACT

Nowadays, when the ever-changing market demands bring various innovative challenges to business mechanism of front office, accordingly, management mechanism of back office and resource allocation also transform substantially. In particularly, formation of the demand chain that driven by demands and based on IoT, platform mechanism and etc. urges the management of supply chain that has been serving customers and market demands as cornerstone over a long period of time to be confronted with challenges of incremental disintegration and radical transformation.

In this paper, we first illustrate and analyze the evolution from supply chain to demand chain systematically. After that, detailed solution scheme regarding the construction of demand chain is elaborated, and real cases are demonstrated to corroborate the operational mechanism of demand chain and its validity. Last but not least, a set of principles is concluded for the construction and operation of demand chain, which is also a provision for the perfection of demand chain and settlement of challenges.

Keywords: Supply chain, Demand chain, Demand driven platform, Reorganization of resources
INTRODUCTION
Along with the unceasing innovations of organizational operations and development of ICT, not merely the value chain that assists businesses in orientating strategic dominance, but also the supply chain that sustains and enhances operational efficiency among businesses have undergone enormous transfer and breakthrough.

For the traditional framework of supply chain which resembles the value chain of business, links from the acquirement of raw materials to the delivery of finished products to consumers need to achieve right things, right time and right location. In the meantime, both the products and the links regarding service have to retain high quality. To assure the above, Management of supply chain is supposed to be prompt, comprehensive and accurate; and this can be completely realized in the theoretical linear structure. Nevertheless, in the real net structural supply chain, condition turns to be considerably complicated, especially for industries such as automobile and aviation in which thousands of components be manufactured, assembled and deployed. Management and control of human can barely cope with the enormous network structure. Though countless unsolved issues have been resolved with the efficient auxiliary operation of ever improving business communication system.

On the other hand, it is apparent that nowadays, substantial enterprises in industries such as PC industry, automobile industry and service industry can hardly sustain with traditional supply chain notions. Seethamraju states that increased product variety, compressed cycle times, supply chain network based competition and the uncertainty in business environment are forcing organizations to shift their emphasis towards demand chain management (Seethamraju, 2014). This is due to the uncertainty of market demands and industry characteristics, and it leads to a transfer that more and more enterprises orientate demand firstly, and then commence research and development, marketing, and exploitation of channels on the definite demand. Procurement of raw materials and manufacture are conducted upon explicit market positioning. This process entirely overturns the traditional supply chain mechanism orientated by supply, turning into a type of mechanism orientated by demand.
THE MECHANISM OF DEMAND CHAIN

When we mentioned demand chain in the past, we considered it as nothing but a kind of supplementary of supply chain, whose actual effects coincide with CRM. While in enterprises such as Tesla, Amazon and Apple, explicit positioning of demand is first conducted, then platform is established through various approaches, or third party platform is exploited for the reinforcement of demand. Finally, supply of products/services is carried out. The core of traditional supply chain has converted to a constituent in assisting the establishment of demand chain.

In a demand-based environment the end-user or the customer is the key influence to the demand source (Bumblauskas, D., et al., 2016). The demand chain we mention here is an open and platform-type networking system orientated by demand. Upon the definiteness of demand and the formation of prolonged collaboration with proactive consumers, R&D of products and services is expedited and advanced with the predominance of platform. Meanwhile, platform and network effect is exerted in exploiting unattained market and consumers. Online and offline roles are also utilized to amplify channels of marketing and delivery. Then, with the allotment pattern of raw materials and products in conventional supply chain and the ever-evolving manufacturing technique, ultimate products and service become accessible. While the execution and supervision of the above procedures are in need of the backing of a brand new Management Information System based on IoT (see Figure 1).

Specifically speaking, firstly, to achieve the precise and prompt detection and determination of demand, the cooperation regarding research, and the extension of market requires instantaneous and appropriate interaction between market and consumer, and feedback from consumers as well, while the most applicable approach to realize the above is the IoT technology based on intellectualization and socialization. Secondly, when it comes to the operation of manufacture and logistics, the IoT background which revolves around oriented tracking and secure transmission are more necessary as a foundational assurance. Furthermore, for medium and small size enterprises such as Kabuta and Rakusl we introduce as following, targeting at becoming the core of demand chain and operating it, the successive enhancement and
enlargement of demand chain is a precondition, and this is based on the assurance of better diversification and alternation between demand and supply which is ensured by continuous innovation of technology that can meet the ever-growing demand of demand chain participants.

![Image of Demand Chain Mechanism](attachment:image.png)

**Figure 1. Illustrating the mechanism of demand chain**

**THE EXEMPLIFICATIONS OF BUILDING DEMAND CHAINS**

To make a more distinct illustration of the structure and application of demand chain, we will introduce two real cases in the following part.

*Kabuta Corporation*

The first one is the case of venture company – Kabuta Corporation, which maximize the notion of intelligent distribution platform through Virtual Manufacturing Factory. The company initially aimed at connecting the designers or enterprises which have the ideas of new products while are weak in terms of manufacturing with medium and small businesses which possess manufacturing technologies which lack new ideas. With the 3D printing technology and device of these businesses, a demand chain system based on intelligent distribution can be constructed.
Specifically speaking, it is to collect the 3D printing data of designers or enterprises through internet, and then transfer it to medium and small businesses with the network of kabuta, finally, trial productions are made in these businesses with their 3D printers. If new orders of clients are made at enterprises or designers, Kabuta will assign the most appropriate business or factory to perform the production and distribution through the network. All the above operations are completed on the intelligent distribution platform through the virtual space of cloud. What is most substantial, with intelligent distribution platform, Kabuta developed its original management system, which can grasp the situation and position of free 3D printers and the requests of 3D data; ideas are transferred through the platform, and information regarding situation and position of 3D printer are gathered through the management system. The whole process realizes efficient and prompt distribution of requests and production.

Utilizing the mechanism of demand chain, Kabuta not only extend and strengthen activation and systematization of medium and small businesses and craftsmen, but also provide similar assistances to big enterprises.

**The Printing Network of Raksul**

Here is a case in printing industry, in which manufacture capacity and situation of medium and small printing factories are linked to requests of buying parties, and the utilization of the mechanism of demand chain enables the enhancement of efficiency and the diminishment of cost. Rakusuru.com was initially a company which utilized Internet to receive printing businesses, and then allocated these businesses to other printing factories to finish the printing through its network. During the process of operation, the company found out that in traditional printing industry, due to the low efficiency of multiple composition, earnings of numerous medium and small subcontractors are lowered substantially, and operation availability of devices are also difficult to be enhanced. Meanwhile, as buying party, its cost on printing had been rising constantly. In the whole industry, a vicious circle had been developed.

Aiming at the resolution of this, Raksul focuses on the characteristic that the deviation and variation of the availability of devices are substantial while requests are dispersed. Utilizing its
demand chain composed through factories, the company link the requests of both parties and resolve their issues smoothly.

In detail, as the variation in range, scope and field, the jobs different businesses can receive are varied. Accordingly, situations of overload and unused take place every now and then. With the adoption of its own network, Raksul can detect the operation situation of devices in these factories and assist them to maximize their manufacture capacity. Moreover, as Raksul’s most clients are medium and small businesses whose demands are varied in terms of quality and quantity, to satisfy their demands to the utmost, the company has been expanding and combining the available resources using its platform so as to content buying parties with lowered cost.

CONCLUSIONS

As technology innovation and market progress enormously, the management pattern of intra-and-inter organization has gone through tremendous transformation, in specialty, the supply chain management mechanism that assists in the maintenance and enhancement of coordination among enterprises is also confronted with various challenges. The emergence of certain rising and novel enterprises that break through conventional supply chain mechanism or pattern enables the demand driving demand chain mechanism which could only be prospected formerly to turn up distinctly and be verified.

In this paper, we first illustrate and analyze the evolution from supply chain to demand chain systematically. After that, detailed solution scheme regarding the construction of demand chain is elaborated, and real cases are demonstrated to corroborate the operational mechanism of demand chain and its validity. Last but not least, a set of principles is concluded for the construction and operation of demand chain, which is also a provision for the perfection of demand chain and settlement of challenges.

ACKNOWLEDGE
This research is supported by Grant-in-Aid for scientific Research of the Japanese ministry of Education, Culture, Sports, Science and Technology under the Contract No.(C) 16K03832(2016-2018).

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Strategies for Improving Supply Chain in Craft Brewing Industry

It’s no secret that Americans love beer, especially when it’s made of natural ingredients and produced locally. This theory is supported by the craft beer boom that’s currently taking place throughout the United States. The craft beer market made approximately $19.6 billion dollars in sales in 2014, which was 22% growth from the previous year (Goldschmidt). On average, there are two breweries being opened per day and a record total of 3,418 craft breweries in the US as of 2014 (Littman). Defining craft beer is a difficult task because everyone seems to have their own take on its meaning, and that meaning appears to change as each year goes by. The Brewers Association categorizes craft brewers as small, independent, and traditional (Littman). The issue with that definition is that many craft breweries, which were once small, are now experiencing substantial growth, yet still considering themselves in the craft category. While the owners of these new breweries are brave and creative individuals, often times their business acumen could often use improvement. Opening a brewery is a complicated experience that usually results in the owners being more preoccupied with creating interesting beers and designing artistic labels, as opposed to focusing the operations side of the company. However, a few simple solutions to a brewers supply chain could make their companies much more efficient.
Structuring and Managing Complex Adaptive Supply Chain Networks

Introduction

There is increasing recognition that effective supply chain management can lead to improved performance and competitiveness (Cecere et al. 2004; Vickery et al., 2003; Pettit et al. 2010). According to Sheffi (2007: 82), the term supply chain is “a simplification of the supply web or network of suppliers, manufacturing plants, retailers and the myriad supporting companies involved in the design, procurement, manufacturing, storing, shipping, selling and servicing of goods.” Despite its promise, supply chain management is fraught with difficulties. In fact, efforts to manage supply chains have often been met with frustration and our understanding of how to effectively manage supply chains remains rudimentary. One important source of that frustration appears to be their very nature: supply chains are made up of autonomous firms with their own interests and strategies and a high degree of interconnectedness and interaction in an environment that may be changing rapidly (Choi & Hong, 2002). Worse yet, supply chains are open to all sorts of risks, and vulnerabilities, some man made, and others outside of human control (Pettit, Fiskel and Croxton, 2010; Marchese, Paramasivam & Held, 2012). Sheffi (2007: 11) may have put it best when he notes that “although responsible for high levels of customer service and low costs, modern supply chains also bear the seeds of vulnerability to high-impact/low probability events.”

Our traditional ideas of managing interdependence, interconnectedness, uncertainty and surprise seem unsuitable to unraveling what is clearly a complex and dynamic phenomenon. At some level, existing mindsets for understanding supply networks seem to rest on a traditional Cartesian-Newtonian worldview of control, efficiency, system optimization and strategic self-interestedness behavior. That approach views supply chains as static systems in which the goal is system optimization (see, e.g. Gunasekaran & Ngai, 2005; Pathak, Dlts and Biswas, 2007). Researchers have also focused on power and conflict as key dynamics in supply chains (Krajewski et al. 2005; Belaya & Hanf, 2014). While insightful, such approaches may yield an incomplete understanding of how to manage a dynamic phenomenon such as a supplier network. Clearly, there is the need for the application of theoretical, and conceptual lenses as well as new metaphors more consistent with the dynamic and evolutionary nature of supply chains and that effort may already be underway.
Intrepid organizational scientists have begun to apply a complex adaptive systems (CAS) (Gell-Mann, 1994) model to our understanding of supply chains and other organizational phenomena. This research extends that stratum of research by exploring the design and governance implications of supply chains as complex adaptive systems. The CAS framework is an emerging worldview rooted in systems theory, evolutionary biology and game theory. As Pathak et al. (2007) noted, researchers across multiple disciplines in the social and natural sciences have significantly advanced the theoretical and methodological boundaries of CAS-based perspective, one that seems more in tune with our understanding of the evolutionary nature of supply chain networks and other related dynamic management phenomena.

Building on the pioneering work of Choi et al., (2001) other researchers have extended our understanding of supply networks as CAS (Pathak et al., 2007; Li et al., 2009). For example, Li et al. (2009) modeled and simulated the evolution of complex adaptive supply networks based on CAS and fitness landscape theory (Kauffman, 1993) to study the evolution of supply networks in the emerging Chinese equipment apparatus industry. Pettit et al. (2010) suggest that management can develop appropriate capabilities to deal with the many sources of vulnerability and risk inherent in supply chains. This ongoing research has focused on one important design goal based on the CAS view of supply chain networks: the idea that such supply networks be designed to be resilient (Ponomarov & Holcomb, 2009; Pettit, Fiskel & Croxton, 2010). Resilience as a property of dynamic models refers to the capacity of a system to adapt to change and deal with surprise while retaining the system’s basic function and structure. A resilient supply chain is one with the adaptive capability to prepare for unexpected events, respond to disruptions, and recover from them by maintaining continuity of operations (Ponomarov & Holcomb, 2009).

Prior studies have extended our understanding of the general principles and rules that govern the evolution of complex adaptive supply networks but important gaps remain. First, our understanding of the key concept of resilience requires further annotation. Resilience may be a desired goal, yet there are different forms of resilience each with its distinct, and sometimes overlapping design and management implications. Second, as social systems, supply chain networks, even as complex adaptive systems, require human intervention. Specifically, unlike natural systems, organizations and their managers have capabilities
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to intervene and influence the evolution and trajectory of supplier networks. Despite that, the existing research seems to have somewhat neglected the integration of social dynamics into complex adaptive systems’ theories of supply chains. Third, the nature of CAS is such that we cannot completely design them, and therefore governance and management issues are equally important. How supply chain actors share power and make decisions to ensure the system’s long term survival is important but less discussed in the literature. Finally, the many emerging metaphors borrowed from complexity and dynamical systems theory have important design and management implications that have yet to be fleshed out in the supply chain literature. For example, Christopher & Pettit (2004) suggest that we can design supply chains ahead of time to promote their resilience. Pathak et al., (2007) have called for additional research on that and similar issues and this research, in part, responds to that call.

This paper seeks to bridge some of the existing gaps by providing a framework for understanding the design and governance implications of conceptualizing supply chain networks as CAS. We structure the rest of the paper as follows to explore the issues: The next section outlines the common properties of CAS. The section after that examines three different forms of resilience, and the concept of fit. The design, governance and management implications of each of these are discussed. The concluding section explores the research and practice implications of the paper. Figure 1 is a graphic representation of our organizing framework. It includes key mechanisms for enhancing the ecological, engineering and social resilience of CAS-based supply chains and how these relate to their long term stability and performance. We also explore the processes through which supply chains co-evolve with their environments. Performance is discussed in terms of the long term profitability and stability of the supply chain.

This paper makes significant contributions to research on supply chain design and management. First, by integrating the social dimension into complex adaptive systems, this study extends our understanding of CAS-based supply chain networks. The integration of the social dimension into complex adaptive systems and supply chain network literature is important given that supply chain networks are partly socio-technical systems and not living organisms. Second, the paper contributes to the supply chain literature by exploring the governance and design implications of supply chains as CAS. Both design and
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management issues are important since we cannot design complex adaptive systems for stability. Third, this paper sheds new light on resilience, a key concept in the supply chain literature, by showing that resilience may vary across the evolution of supply chains; engineering resilience may offer short term efficiency but not promote long term stability while both ecological and social resilience promote greater performance and stability in supply chain networks. Finally, the framework provided in this research may allow us to derive a set of practical guidelines for supply chain network design and management.

The model of governance and design described in this research borrows from existing work in natural resource management and ecology, disciplines in which phenomena have been conceptualized as CAS (Holling, 1973; Gunderson et al., 1995). We argue that conceptualizing supply networks as CAS is an important conceptual advance; one that has both design and governance imperatives, since we cannot design any fail-proof blueprint model for managing in dynamic systems. We also suggest that the CAS lens, while helpful, omits the social dimensions inherent in supply chains. Specifically, we argue that social resilience theory, adaptive governance and related ecosystem management models such as adaptive management and adaptive capacity (Gunderson, Holling & Light, 1995) are best suited to understanding the design and managerial imperatives of complex supply chain networks. In this proposed framework, complex supply chain networks can be thought of as complex adaptive social ecosystems since both complex adaptive systems and social-ecological systems exhibit co-evolution, dynamism and non-linearity, and system complexity (Folke et al., 2005). Our framework particularly highlights the role of social capacity in the effective governance of supply chains networks. As Folke et al. (2005) observed, exploring social sources of resilience of complex systems may be useful especially to understanding system behavior particularly during times of abrupt, disorganizing or turbulent change. Within this framework, power and control are de-emphasized in favor of inter-actor trust, collaboration and shared governance. The overall agility of the system over time is substituted for a focus on system efficiency alone; building the capacity for self-organization replaces arbitrary system intervention and a focus on both individual and systems...
learning, as opposed to organizational learning alone, all geared toward enhancing the long term operational and leadership capacity among all firms in the supply chain. The framework links both individual agent and collective behavior to the stability of the system as a whole because we know from previous research that individual choices in supply chains can have global effects on supply chain networks (Sheffi, 2007).

Following Morse et al. (2013), we conceptualize supply networks as social complex adaptive systems as a way of bringing the social dimensions inherent in supply chains into complex systems and explore their design and governance implications. As Morse et al. (2013) note, social systems constrain and enable actors’ actions even in complex adaptive systems. Moore et al. (2003) suggest that individual actors have the power and capability to affect outcomes that arise from both internal and external pressures in ecological systems. Research on supply chain resilience has shown that firms as individual actors can develop their capabilities and capacities for reacting to vulnerabilities (Sheffi, 2005; Pettit et al. 2010). The extension of social theory to the study of complex adaptive systems is an acknowledgement of the role of the human dimension in shaping such systems. As Pettit et al. (2010) noted, we need a broader view of resilience than existing research suggests; resilience in supply chains should encompass all supply chain processes, relationships and responses to vulnerabilities.

It may seem contradictory at first thought to suggest that design has a place in a CAS with self-organizing capabilities. Truly understood, self-organization seems more like a random process while design implies purposeful behavior in which an organized process is determined by human desires. It is indeed true that self-organization suggests a certain degree of natural selection. However, since patterns at the global level of such a system emerge solely from the numerous interactions among the lower-level components of the system, rules specifying interactions among the system’s components are executed using only local information, without reference to the global system (Camazine et al. 2001). Also, despite their complexity, such systems may be explained by a small set of simple rules because simple rules applied again and again can lead to complex behavior (Reynolds, 1987). One implication of this property is that purposeful action can be used to both specify those simple rules that determine behavior in a complex
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system as well as encourage behaviors that promote self-organization. The emerging supply chain literature provides some evidence that individual firms engage in their localized decision-making, for example, by selecting capable suppliers. Choi et al. (2001) demonstrate that individual firms can specify the simple rules through their purposive behavior, even if they cannot control what emerges at the system level because of self-organization, leaving firms that are capable of adapting with evolutionary changes in the system to be more successful than those that are slow to change.

Complex Adaptive Systems

Complex adaptive systems theory builds on general systems theory (Bertalanfy, 1968). A complex adaptive system consists of a number of active elements, known as agents, which interact with each other according to sets of rules that require them to examine and respond to each other’s behavior in order to improve their behavior and the behavior of the system they comprise (Stacey, 1996: 10). In the case of supply chains systems, the agents (firms) interact by exchanging information and physical goods. Complex adaptive systems have some common characteristics: co-evolution and adaptation, emergence and self-organization (Choi et al., 2009).

First, complex adaptive systems co-evolve and adapt to their environments. Co-evolution is the process by which a CAS interacts with its environment to create dynamic emergent realities. Choi et al. (2009) note that co-evolution ensures that changes in the environment may cause the agents to change, which in turn may cause the environment to change because there are feedback mechanisms at play. Adaptability represents the capacity to adjust responses to changing external drivers and internal processes to retain stability (Folke et al., 2004). CAS are recursive by nature, meaning that changes in the individual entities of the system can cause the entire system to change overtime because the individual components that make up the system are capable of responding to changes in the environment (Pathak et al. 2007).

Second, complex adaptive systems self-organize because they co-evolve and adapt with the environment. Self-organization is a process in which “new structures, patterns, and properties emerge without being externally imposed on the system” (Choi et al, 2009, p. 354). In a self-organizing system,
order emerges without any external control (Nicolis and Prigogine, 1989). Despite the absence of control, self-organizing systems display a considerable level of regularity, stability and adaptability because individual agents in the system interact directly with each other and the behavior of each entity is influenced by the behavior of its immediate peer instead of all entities in the system as a whole (Capra, 1996). Another important characteristic of such self-organizing systems is that even without any external steering of the changes in the system, such systems self-organize towards a certain state of dynamic equilibrium (Bak, 1997). Self-organizing systems exhibit nonlinear behavior with changes in such systems producing disproportionate outcomes: small changes can have dramatic effects on the system, the so-called “butterfly effect,” a metaphor Lorenz (1963) uses to describe how small perturbations can have dramatic effects on weather patterns. Surana et al. (2005) in fact equate the “bullwhip” effect in supply chains to the butterfly effect. Predicting the future in such a dynamic system is difficult, if not impossible, and the best we can probably hope for is to look for patterns and the key things to which the system seems to be drawn, what Lorenz (1986) christened “attractors.” An attractor is simply a state of dynamic equilibrium in which minor variations and changes can occur either spontaneously or through self-organization as a response to internal and external pressures (Loorbach, 2007).

Complex adaptive systems also demonstrate emergence. Emergence is the “arising of new, unexpected structures, patterns, properties, or processes in a self-organizing system.” (Zimmerman et al. 1998, p. 265). According to Baas (1994), emergence occurs when something happens in the course of the interaction among a system’s parts that produces a feature of the system that was not present when the individual parts were considered separately. Loorbach (2007) notes this quality of complex systems suggests that we cannot understand the “global” behavior of such systems by analyzing the local behavior of individual actors or components of the system since the behavior of individual actors is different from that of the entire system. Other properties of complex adaptive systems are that they are nested, meaning the components or agents of the CAS are themselves complex adaptive systems and such systems undergo transformation. Transformability is the capacity to cross thresholds, enter new development trajectories, abandon unsustainable actions and chart better pathways to established targets (Folke et al., 2010). Pathak
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et al. (2007: 562) proposed that supply networks could be viewed as a CAS consisting of interconnected, heterogeneous, autonomous firms that interact actively much like agents in CAS-based supplier networks that make choices concerning their adaptation and survival. As Li et al (2010) note, the concept of complex adaptive supply networks allows us to understand how supply chains adapt to, and co-evolve with the dynamic environment in which they exist, and to identify patterns that arise in such a condition of co-evolution.

**Resilient Supply Chains**

Resilience has rapidly emerged as an important concept in the supply chain literature. A resilient supply chain is proposed as a buffer against supply chain risk and vulnerability; the suggestion is that we can design resilient supply chains to overcome their inherent risk and vulnerability (Ponomarov & Holcomb, 2009; Pettit, Fiskel & Croxton, 2010; Christopher & Peck, 2004; Sheffi, 2005; Peck 2005).

Resilience has been defined in the natural and social sciences as “the capacity of a system to experience shocks while retaining essentially the same function, structure, and therefore identity (Walker et al. 2004). The heuristic of a ball and bowl on a table is used in resilience theory to illustrate properties of such systems. We can think of a tall narrow bowl with steep sides and a bowl with a more shallow sides, e like a saucer. When at rest, the balls in the bowls sit at the bottom of the bowl, at equilibrium. Ruhl (2011) notes that when the table is shaken around, both balls roll but in different ways. The ball in the narrow vase stays near the bottom and has quick recovery, whereas the ball in the shallow saucer might roll all around, reaching far from the bottom, but resist spilling over the rim. In resilience terminology the bowls represent the “basin of attraction” or the current system behavioral state. The bottom of the bowl represents the “attractor” or equilibrium state, and the form of the basin defines the “latitude” within which the system state can move before crossing a threshold which, if breached, makes recovery to the equilibrium difficult or impossible. The wider the basin, the greater the number of system states that can be experienced without crossing the threshold.
Engineering Resilience

Holling’s (1973) seminal work on resilience identified two different forms of resilience: ecological and engineering each with very distinct design goals. Both concepts of resilience are alike in one respect: both envision a system that has been pushed off its equilibrium state by a disturbance but they differ in terms of the mechanisms and strategies the system uses to avoid being pushed so far as to be functionally restructured. Using the bowl and ball heuristic, engineering resilience strategies can be represented by a ball at the bottom of the tall narrow bowl, while ecological resilience strategies produce a shallow wide bowl. A system’s reliability, efficiency and robustness may be indicative of its engineering resilience (Alderson & Doyle, 2010).

Engineering resilience is measured by the time required for a system to return to an equilibrium state following a disturbance. Engineering resilience draws on reliability, efficiency, and quality control of a system to pursue a single objective: return the system to equilibrium state after a disturbance making recovery a design goal. A system that favors engineering resilience will tend to be highly resistant to change because of its inherent rigidity. Such a system, however, would be vulnerable to large scale disruptions if internal and external shocks break its resistance. Holling and Gunderson (2000) suggest that engineering resilience devotes all its resources to staying near the equilibrium, so that the system can snap back after a shock. The authors suggest that focusing on engineering resilience exclusively “reinforces the dangerous myth that the variability of natural systems can be effectively controlled, that the consequences are predictable.”

Engineering resilience strategies such as efficiency would remove, at the design stage, anything it perceives as wasteful redundancy. For example, it will be highly efficient to use lean manufacturing approaches such as Just-In-Time (JIT) delivery to accomplish engineering resilience. Indeed, Marchese et al. (2012) note that supply chain strategies focused on reducing operational risk depend on lean manufacturing, Just-in-Time inventory and capacity rationalization to boost supply chain efficiency.
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Qunflesh & Tarafdar (2013) have suggested that lean supply chain management actually helps supply chain performance. While such approaches may make businesses more agile and responsive, they reduce slack in the supply network and also reduce the margin for error and amplify disruptions, making firms more susceptible to vulnerability because the approach substitutes efficiency for wider recovery options in the event of a shock to the system. Engineering resilience is only useful in the long run if all possible or most of those inefficiencies are known and removed at the design stage, a situation that is not always possible.

Another engineering resilience approach includes the focus on conformity and compatibility that accompanies the search for quality in supply networks. Suppliers must deliver defect-free shipments or risk destabilizing relationships and engineering resilience. However, as Choi and Hong (2002) observe, firms using such universal quality standards such as ISO 9000 and “Six Sigma” may be trying to impose too rigid control on complex systems. The authors cite the examples of such notable firms like Motorola, IBM and Daimler Chrysler as examples of firms who tried, unsuccessfully, to use institutional strategies to achieve efficiency in their supply chains. The authors note that popular control-oriented schemes such as JIT may be substituting long term performance for short term efficiency in supply chain networks. Other examples of supply chain networks demonstrating engineering resilience qualities abound. Supply chains with engineering resilience include those dominated by sequential, multi country production models where bits of value get added here and there. Fisher (2011) reports that some Japanese supply networks had a hard time recovering after the 2011 Tsunami disaster because in trying to provide better quality at lower prices, manufacturers picked very narrow, optimized supply chains, thereby putting all their eggs in one basket (Fisher, 2011). It is reported that a number of Japanese companies have learned the lessons of focusing on too much efficiency (engineering resilience) and have already started investing in redundancy with Canon reported to be considering a move to diversify its production base by expanding from its southern Japan sources, and increasing production lines at its two factories in China (Fisher, 2011).

If one can predict system evolution and future problems of the system with some certainty at the design stage, then efficiency and engineering resilience strategies would seem appropriate. If the reverse is
true, then using engineering resilience strategies would increase system failure and therefore other resilience strategies would seem most appropriate. The long term stability of a system with high engineering resilience may be in doubt because such systems tend to be rigid and unable to adapt making them vulnerable to both internal and external shocks. Therefore,

Proposition 1a: The higher the control and efficiency-based approaches associated with a CAS-based supply chain network, the higher the engineering resilience.

Proposition 1b: The higher the engineering resilience of a CAS-based supply chain network, the lower its long term stability as engineering resilience substitutes short term performance for long term stability.

Ecological Resilience

Ecological resilience differs in many respects from engineering resilience. Ecological resilience is measured by the amount or magnitude of disturbance a system can absorb without having its fundamental behavioral structure redefined, a property known as resistance (Gunderson and Holling, 2002). This form of resilience relies on adjustments to system processes as a means of managing overall system integrity and favors resistance as the design goal. Unlike engineering resilience, ecological resilience accommodates the possibility of fluctuations within a basin of attraction, with the goal of being able to “flip” from one structural state to another. As Gunderson & Light put it, engineering resilience is concerned about the efficiency of a system, ecological resilience is concerned about the very existence of the system. Ecological resilience has at least three design imperatives.

Redundancy

One important means for promoting ecological resilience is maintaining redundancy and a diversity of system components (Gunderson and Holling, 2002). Gunderson and Holling define functional redundancy as the “diversity of the responses to disturbance among the species or actors contributing to the same function in social-ecological systems.” Functional redundancy implies the presence of multiple components that can in effect perform the same function so that a failure of one component is not fatal to the system as other components in the system can compensate for the loss in the system. In its simplest terms, redundancy, much like portfolio diversification theory teaches us “to avoid putting all our eggs into
one basket,” so to say. Redundancy opens up the response diversity of a system. Response diversity enhances resilience because it opens up options. Response diversity would tend to be higher when there are differences in the capacity of the components so that it makes it unlikely that a particular disruption would present the same risk to all the components at once.

Related to supply chain management, a key implication is for firms to diversify their supplier base and parts components. Research evidence has shown that systems and supply chain networks with many different components are generally more resilient than those with fewer components. Sheffi (2007) reports that the impact of Hurricane Mitch in 1998 on banana supplies to Chiquita and Dole were different. Dole lost 25 of its global banana suppliers as a result of the hurricane, but because Chiquita had more varied suppliers from such far flung places as Ivory Coast and Australia, it moved quickly to leverage these other suppliers. As Biggs, Schluter & Schoon (2015) argue, redundancy is more valuable when response diversity of a system is higher, especially where the components providing the redundancy function also react differently to change and disturbance as the Chiquita example demonstrated; the hurricane in South America did not affect banana producers in West Africa and Australia.

The lesson here is that firms can build redundancy into their supply chains to enhance ecological resiliency. This may prove a critical quality in supply chains as they open up the response options available to supply chain members. Sheffi (2007) suggests ways that supply chain members can build redundancy into supply chains without increasing costs: (1) develop supply chains in which products are not customized to the user’s requirement until the last possible point; (2) develop part and platform commonality and modular designs so same parts can be used in multiple products (3) increase the use of standard rather than special parts, and (4) use flexible contracts that allow for changing quantities and delivery times among supply chain members. Other researchers have also emphasized flexibility as a capability that confers redundancy and therefore multiple options for recovery in the event of disruptions in the supply chain (Tang, 2006, Fiskel, 2003; Petti et al. 2010). Redundancy as a strategic option for increasing resilience comes at a cost: it may promote some inefficiency. These include the possibility for duplicating effort and building multiple competencies may lead ultimately to higher transaction costs. The flip side of this, and
that is more beneficial to the resilience of the supply chain, is that redundancy allows the system to absorb shock and disturbances that may be unexpected, but bound to happen in every complex adaptive system. The challenge for supply chain design is whether to focus on efficiency of function or the long term stability of the supply chain. Clearly the long-term survival of the supply chain is a preferred option.

Designing for Flexibility

Another way of increasing response capability is flexibility of actors and systems. Flexibility reflects the ability of a system to respond rapidly to changes occurring inside and outside the system (Garavelli, 2003). Flexibility is both similar to, and can be an alternative to redundancy. Supply chain flexibility has been a subject of sustained research (Upton, 1994; Stevenson & Spring, 2007; Kumar et al. 2008). The existing treatment of flexibility in the supply chain literature seems largely focused on what options individual actors used to adapt to changes. For example, Kumar et al. (2007) summarize this research showing that firms use product development, manufacturing, sourcing, logistics and information system flexibility. The use of common parts, modular designs, alternate distribution channels, multi-sourcing and similar inventory management techniques among others can all be used to increase flexibility (Pettit et al. 2010; Christopher & Holweg, 2011). For the most part, this literature emphasizes properties of individual actors as these can all be considered strategic options that individual supply chain actors can use to respond to changes or surprise. Few studies have looked at system-wide or supplier network flexibility (see Golden & Powell, Krajewski et al. 2005 for some exceptions).

There is little doubt that flexibility as a strategic option benefits individual firms but system-wide flexibility is also important. For example, Sheffi (2007) describes how Intel used this capability effectively to service during the SARS scare that struck Asia in 2003. By building its fabrication plants to the same exact specifications, Intel was able to create interchangeable processes and fabrications throughout the world. Marchese et al. (2012) also report that after the 2011 Japanese tsunami, companies with flexible manufacturing and supply chain capabilities generally recovered more rapidly than their non-flexible counterparts. The authors cite the example of a leading printer manufacturer that was able to restore
production to pre-disaster levels in less than four months because it had diversified its parts production to mainland China and various areas throughout Japan.

Whether agent flexibility translates to system-wide flexibility is open to some debate. However, since the internal behavior of agents in a complex adaptive system affect the system as a whole, agent behavior could affect system behavior if it is coordinated. At the same time, however, because these forms of flexibility look more like engineering resilience with a focus on efficiency and short term gain, their impact on long-term system flexibility may be questionable. It would seem that actions that promote system-wide flexibility would be particularly helpful. Incidentally, preliminary insight suggests such policies and programs are more reflective of ecological resilience. For example, inter-firm collaboration, including the sharing of information among supply chain members, has been shown to foster supply chain flexibility (Stevenson & Spring, 2007). If agents adopt shared norms around flexibility, build social capital, trust, and engage in collective learning, system-wide flexibility can be developed.

*Build in Attractors: Creating Opportunities for Self-Organization*

Another strategy for building ecological resilience is to create the conditions for self-organization in the supply chain. As mentioned elsewhere in this paper, CAS self-organize towards a certain state of dynamic equilibrium (Bak, 1997). Although dynamic systems exhibit unpredictable and discontinuous behavior, such systems invariably are pulled toward some point or an attractor. Like resilience theorists, earlier systems theory held the final state of equilibrium as an attractor. In chaos theory, an attractor is simply any spot, point or location within an orbit that seems to pull the system to it (Briggs and Peat, 1989).

The concept of attractors and basins of attraction may provide one way of teasing out how to design dynamic and complex systems ahead of time to create opportunities for self-organization. Coleman et al. (2008, p. 1458) define attractors as “a state or reliable pattern of change towards which a dynamical system evolves overtime and to which the system returns after it has changed.” In generic terms, an attractor refers to a subset of potential states or patterns of change to which a system’s behavior converges overtime. Attractors, in effect, represent the long-term dynamics of a system so that whatever the initial conditions, systems overtime get “attracted” to the attractor in its basin. Coleman et al. (2008) notes that systems may
have more than one attractor. There are at least four management implications for supply chain design from the properties of attractors.

First, the wider the basin of attraction, the greater the range of capabilities and options available to the actors. For example, the supply chain actors can use flexible sourcing strategies such as supplier contract flexibility (Fiskel, 2003) multiple uses for supplies (Peck, 2005) or adaptability strategies such as fast re-routing (Sheffi, 2005) to remain within this basin. The narrower basin of attraction, B, implies that actors have a narrower range of options and are focused mainly on efficiency of the supply chain. To that end, strategies such as waste elimination, product variability reduction and failure prevention will be the goal.

Second, the depth of an attractor provides an index of how difficult it will be for actors to adapt when faced with turbulence and supply chain vulnerability. Sticking with the ball heuristic, if one tries to push the system out of basin B uphill, the ball will roll back to the basin as soon as that effort is relaxed. If however, there is sufficient push to dislodge the system from its current attractor state, say B, the system will gravitate toward another attractor. Third, it may also be possible to build “desirable” attractors into the system as well as influence which attractor a system moves toward. As Seel (2008) notes, although it is not possible to dictate the nature of the attractor because a complex system is intrinsically unpredictable and uncontrollable, it may be possible to influence the nature of the attractor which the system ‘chooses’ in social systems. For example, encouraging supply chain members to develop capabilities for flexibility, a culture of risk management and a greater ability for change would be tantamount to influencing the nature of an attractor. Finally, dynamical systems theory informs us that our capacity to influence complex adaptive systems, at least in social systems, may be greater than the theory suggests. Here it is useful to reiterate that simple rules, applied again and again can lead to complex behavior and at least one organization may be applying this to manage complexity. Seel (2008) reports that the US Marines are using this principle to increase flexibility when command lines may get broken (keep moving, use surprise, and take higher ground wherever possible).

One main conclusion from resilience theory is that when variability is high and predictability is low, ecological resilience strategies are more likely to prove successful while engineering resilience
Proposition 2: Redundancy, flexibility and attractors facilitate the long term stability of CAS-based supply networks by enabling higher levels of ecological resilience

Co-Evolution & Adaptation: Fitness Landscapes

The environment generally places demands on firms and supply chains face an environmental fitness landscape (Li et al. 2009). Choi et al (2001: 355) note that complex adaptive systems that evolve maximize some measure of “goodness” or fit. The authors note that the potential states that a system can attain may be represented by “landscapes” and the “highest point in this landscape may be considered the optimal state for the system.” One goal in resilience theory is moving the system to a fitness landscape (Kauffman, 1996). Incidentally, nature seems to face similar challenges and lessons on how species evolve and survive in constantly changing environments may hold some clues for supply chains since both species/nature systems and supply chains are complex adaptive systems. Specifically, the concept of fitness landscapes may be insightful with regards to designing supply chains for their long term performance and knowing the types of strategies species adopt to survive under changing circumstances may give us clues on the nature and types of strategies we can develop for supply chain survival. Fitness landscapes is a model from biology where it is used to describe the “fitness” of a species, or more specifically a genotype within a particular environment (Kauffman, 1993). Kauffman suggests that a snapshot of an environment at a given time could be thought of as a landscape. The fitness landscape concept describes evolution as a search for the best possible solutions to a given environmental condition. Kauffman (1995) notes that fitness landscapes can take various shapes and form different topologies. Some landscapes may have only a single high point while others have random landscapes with lots of jagged peaks and valleys. The goal for species evolution is a quest to stay on the highest elevations or peaks of this landscape and receive the highest payoffs.
(chances of survival). However, landscapes are not fixed like a mountain range but are constantly changing and moving, co-evolving with their environment, therefore strategies that make for survival today may not be the same in the future. According to Kauffman (1996, p. 166), agents can improve their fitness by following what he calls an “adaptive walk,” that is by moving one step on the landscape and testing its fitness. If the new location is fitter than the old, it takes another step. If the new location is less fit than the old it returns to its previous location. According to the author, while helpful, adaptive walks may not be the best strategy for optimizing survival chances as both the system and environment are co-evolving and one may have to climb down a valley (less fit position) before getting back to a higher peak as they try to optimize their survival chances by searching for the highest peak.

Kauffman (1996) discovers a technique he calls “patching” which seems to offer a feasible solution to this problem. Patching breaks a system into connected chunks which then try to self-optimize. For example a supply chain may be decomposed into its separate components, say from those providing raw materials, transportation, manufacturing firms in the chain etc. Each actor is then encouraged to improve its own fitness. One possible unintended consequence of success for any given patch may be to cause neighboring patches to be worse off temporarily (go down a valley) and this may lead to the organization becoming worse off for a time. In fact, Choi et al (2001) noted that a supply chain in which one firm seeks to optimize their own local costs may create overall system oscillations (the “bullwhip effect”) that may aggravate the system cost. However, if the process is allowed to continue it will lead to eventual improvement as the system climbs a new peak, one that could not have been reached by a simple adaptive walk.

A fitness landscape for a supply chain is made up of all the agents in the chain. Any action by any one player in the chain affects the whole supply chain because of the interdependencies and survival requires that supply chains have a fit with their environments. There are design implications for conceptualizing supply chain evolution as a search for fitness landscapes. First, it suggests that supply chain actors understand that there can be no fixed solutions or strategies that assure performance in supply chains over time. What works at a given time may not necessarily be suitable at another time. The fact that any
equilibrium or stability may only be temporary suggest that supply chain actors need to create dynamic supply chain management strategies; they must constantly be studying and adapting their strategies if their supply chains are to remain stable. Second, supply chain actors need to adopt multiple, not single strategies, for managing their relationships. Finally, the need for long term collaboration among the agents is important for remaining fit. For example, the concept of patching implies long term collaboration. Each agent in the chain would be encouraged to develop capabilities that increase their individual fitness so that the system as a whole can move to a higher fitness level. Clearly, the need for all actors to develop their individual capabilities or fitness is an important component of the long term fitness of the whole supply chain and some preliminary research has in fact confirmed that long term collaboration is indeed a strategy for long term supply chain stability and performance. Li et al. (2009) have modelled supply chain networks as fitness landscapes using multi-agent technology. The authors measured fitness by customer satisfaction which is evidenced by profit or loss. Their conclusion based on both their modelling and case study is that supply chains demonstrate higher levels of fitness when they adopt long-term collaborations rather than short term strategies. The conclusion is supply networks can affect their own fitness landscapes by the individual or collaborative actions they take. Based on the preceding discussion we propose that

Proposition 3a: The search for fitness landscapes by CAS-based supply networks facilitates long term stability and performance by enabling higher levels of environmental fit.

Proposition 3b: The higher the environmental fit associated with a CAS-based supply network, the higher its stability and performance.

Social Resilience: Governance and Management of CAS-based Supply Networks

Adaptive Management, Adaptive Governance & Adaptive Capacity

A supply chain’s capacity for self-organization can be promoted by building that system’s social resilience and adaptive capacity and emerging work in natural resource management and ecology may provide the
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building blocks for that task. This research has identified adaptive management, adaptive governance and a system’s adaptive capacity as key imperatives for building social resilience and we borrow from that field to understand how to manage supply chain networks for their long term stability and performance. Adaptive management builds on resilience theory. It provides a framework for learning about a system in a way that enhances the agent’s capacity for identifying and reducing uncertainty and surprise (Garmestani et al. 2009). The goal of adaptive management is to build the capacity to reorganize the system within desired states in response to changing conditions and disturbing events (Walker et al. 2004). A key part of adaptive management involves an iterative process of decision making, designed to identify and reduce uncertainty and surprise (Benson and Garmestani, 2011). At some level, adaptive management involves sensemaking (Weick, 1988), a process that allows managers to use information they get about the system to adapt to changing situations as management tries out interventions and learns what works and what does not (Garmestani et al. 2009). Adaptive governance builds on adaptive management. Adaptive governance is about decentralization of decision making and power sharing to promote participation among all stakeholders associated with the system. Supply chain actors may not be used to sharing decision making and power. However, the key implication of adaptive governance is the necessity of stakeholders at every level in a supply network to be shared co-owners who are empowered to make local decisions as they get new knowledge and information about the supply chain. This clearly requires a flexible structure. Excessive centralization of decision making would stifle dynamic learning which should be an ongoing process as new ideas are tested in the network. Decentralization should however be balanced with a certain degree of centralization and accountability for results so actors know what level of decisions they are responsible for in the system as excessive decentralization without accountability can stifle collective learning among diverse stakeholders. Marchese et al. (2012) suggest that companies with resilient supply chains have clearly defined governance structures with clear accountability. Evidence from adaptive management research has shown that two key skills are important for stakeholder’s capacity to deal with surprise and uncertainty for building adaptive capacity. These are the capacity for learning to deal flexibly with new situations and the capacity for sensemaking (Westley, 2002). It would seem useful that supply chain actors
encourage the development of both skills among their members so that collectively, the supply network can increase its capacity to react to uncertainty and surprise.

The purpose of adaptive management and adaptive governance is to build adaptive capacity (Garmestani et al. 2009). A system’s adaptive capacity is the ability of the system to sense threats to system equilibrium and respond by changing resilience strategies without changing fundamental attributes of the system. Ruhl (2011: 1377) notes the adaptive capacity of a system allows the shape of the bowl (from the ball and bowl heuristic) to alter the balance between engineering and ecological resilience strategies. According to Walker et al. (2004), adaptive capacity involves “(1) making desirable basins of attraction wider and/or deeper, and shrinking undesirable basins (2) creating new desirable basins, or eliminating undesirable ones; and (3) changing the current state of the system so as to move either deeper into a desirable basin, or closer to the end of an undesirable one.”

Adaptive capacity requires social memory, social capital, collaboration and learning. How both social memory and social capital are mobilized is important for building ecological resilience (Adger et al. 2005). Social memory has been defined as the area in which captured knowledge about system change and adaptation is stored and subsequently used to deal with change (Berkes and Folke, 2002). Social memory is important for linking past experiences with present and future policies (Westley, 2002). Past changes and the responses that were used are stored in the social memory of individual actors who, if they are in social networks, become repositories of knowledge that is then used during critical times in the system as a whole. In a supply chain, this points to the necessity of building multiple layers of relationships between key boundary people in firms within the supply chain. Besides undergirding trust in the supply chains, key boundary persons by virtue of their ability to share knowledge can constitute an “early warning system” so that members can be prepared for emerging surprises.

Trust, specifically goodwill-based trust, is key to building adaptive capacity. Trusting involves a certain amount of risk because there are no guarantees that trust will be reciprocated or sustained over time. However, when present, trust reduces risk and promotes collaboration. Trust also creates a sense of community and makes social life predictable (Cook, 2003). Malhotra and Murnighan (2002, p. 535) suggest...
that there are two dispositions that are central for trust to be present among people and organizations: (1) a mutual willingness to be vulnerable to each other based on (2) a mutual “expectation of cooperation (or benevolence)” from each other and trust has been mentioned as an important ingredient in supply chain relations (e.g., Ghosh & Fedorowicz, 2008). Sako (1992) proposed three forms of trust in inter-firm relationships: contractual, competence and goodwill trust. The first two are required for any relationship to exist at all, but goodwill trust, often developed within long-term relationships through repeated exchanges, ensures that partners will act in ways exceeding stipulated contractual agreements.

Building trust and informal networks requires investing in social capital. Social capital has been defined as the information, trust and norms of reciprocity inherent within social networks (Woolcock, 1998). Both social capital and trust have been identified as a glue for adaptive capacity (Adger, 2003) and social capital has been shown to strengthen supplier relationships (Uzzi, 1997). Collaboration between all actors who may be operating at different levels is necessary to build a systems adaptive capacity (Folke et al. 2002). Collaboration allows actors to deal more effectively with major issues that sit within an inter-organizational domain, which may not be tackled by any organization acting alone (Vangen and Huxham, 2003, p. 5). The building of informal networks can prove critical especially during times of rapid change as networks will have the flexibility to share novel ideas rather quickly. As Kettl (2000) noted, informal social networks do not completely replace the accountability that exists within hierarchies, but compliments them. The building of informal social networks will lead to the accumulation of social capital. Ruhl et al. (2005) note that social capital increases the flexibility of organizations and institutions as it can become the basis for building adaptive capacity and collaboration. The role of key boundary people in building an informal social network and adaptive capacity has been noted (Klerkx et al. 2010). Such key individuals will provide leadership and guiding vision in their role as knowledge brokers and mediators who sit at the interfaces of the firms. Collaboration in governance networks require leadership (Folke et al. 2005). Leaders can help trust building, sensemaking and provide the impetus for system wide collaboration. In adaptive management, visionary leaders who have the capacity to overcome contradictions and create new syntheses and change people’s mindsets to be more in tune with the new reality will be important (Westley, 2002).
Kim & Mauborgne (2003) describe this sort of leadership as tipping point leadership. According to the authors, tipping point leadership involves four key steps: (1) capacity to break through the cognitive hurdle, making a compelling case for change, (2) sidestepping the resource hurdle by using current resources on areas in need of most change (3) jumping the motivational hurdle by making challenges attainable and making people realize a need for what needs to be done and motivating people with the most influence in the organization, and (4) knocking over the political hurdle by silencing opposition with solid facts.

Adaptive management and adaptive governance should enhance system and individual actor learning both of which are important for building social and ecological resilience (Folke et al. 2005). Garmestani et al. (2014) note that a key area of learning are knowing what constitutes the critical thresholds of the system with the goal of preparing the system for adaptation and resilience. Individual and organizational learning is as important requirement for building adaptive capability (Folke et. all 2005). Learning on the part of each supply chain member is especially important since effective learning will improve their organization’s capacity to take corrective action and deal with ill-defined problems associated with dynamic systems (Nonaka & Takeuchi, 1995). At the system level, learning that questions existing fundamental assumptions will prepare the system to adapt to new fitness landscapes following change. As Becker and Ostrom (1995) noted, management of ecosystem resilience requires the ability to observe and interpret essential processes and variables in system dynamics to develop the social capacity to respond to environmental feedback and change. Ruhl et al. (2005) observe that processes that generate learning and knowledge of the dynamics of the system are useful in developing the social capacity for responding to change. The goal of learning in adaptive management is to learn about the dynamics of the system as a whole rather than detailed knowledge of the parts, because managing for system stability increases the chances that the system will face turbulent change. There is the need for supply chain actors to accumulate abundant knowledge about each other, including knowledge about factors that may cause the system to change and factors that allow the system to reorganize following change. Knowing strategies needed for dealing with surprise and uncertainty would be critical. Indeed, the more they know about each other the
better. This sort of knowledge overlap has been described as knowledge redundancy (Rindfleisch and Moorman, 2001; Sivakumar and Roy, 2004).

Supply chain actors must engage in “double loop learning” (Argyris, 2001) in which basic underlying assumptions, norms and objectives are questioned to stimulate new learning about the system. Double loop learning requires a new mental model as old assumptions are rigorously challenged. It also enables a system to identify whether its mission and principles are still appropriate under the current circumstances. This should be especially important in supply chain management since employees will need to question some of their old models about how to gain advantage and substitute win-lose models for win-win models in relation to their position with other suppliers.

We have demonstrated that social resilience is important for long term stability in complex adaptive systems. In the context of supply chains, firms need to have the capacity for self-organization, develop their adaptive capacity by promoting trust, collaboration, individual and system learning so that such systems can respond appropriately to surprise and uncertainty. The same factors that promote social resilience also have the capacity to influence ecological resilience since these factors promote the long term survival of the system. Therefore,

*Proposition 5a:* The adaptive capacity of a CAS-based supply chain facilitates its long term stability and performance by enabling a higher level of social resilience.

*Proposition 5b:* The higher the adaptive capacity of a CAS-based supply chain, the higher its stability and performance.

*Proposition 6a:* The probability of the long term stability of a CAS-based supply chain network increases as its social and ecological resilience increases

*Proposition 6b:* CAS-based supply chains with ecological and social resilience will demonstrate greater stability and performance than those with either form of resilience alone.

**DISCUSSION**

This research built on conceptual advances in the CAS-based supply chain management literature. Specifically, it explored the design and management implications of conceptualizing supply chains as complex adaptive systems. We presented strategies for fostering the fit, adaptive capacity, self-organization
and overall resilience of a CAS-based supply chain. As Fiskel (2003: 5338) notes, “complex nonlinear systems cannot be modeled by linking together a fragmented collection of linear models. What is needed is new language and new metaphors to describe the relationships and dynamic behaviors that characterize these exquisitely complex systems- a new, multidisciplinary toolkit that begins with connectivity and integration as fundamental themes rather than after thoughts.” Borrowing from work in ecosystems and natural resource management, this research argued that complex systems need to be developed for engineering, ecological and social resilience to increase their capacity for adaptation and transformation.

Considering the nature of CAS, the best we can do is to nurture their resilience. Folke et al. (2003) observed that we can do this by focusing on four critical factors: (1) learning to live with change and uncertainty; (2) Combining different types of knowledge for learning; (3) Creating opportunity for self-organization toward social-ecological resilience; and (4) nurturing sources of resilience for renewal and reorganization.

We have argued that engineering resilience may have long term negative consequences for supply chain networks. However, engineering resilience seems appropriate when we can predict system state, at least in the short term so we can incorporate future variables at the design stage. Complex systems such as supply chains may evolve through a set of landscapes over which we may find engineering and ecological resilience strategies to form modified topographies, depending on where in the system one is looking (Gunderson and Holling, 2002).

Our discussion of attractors as a form of equilibrium state may appear as a desirable design strategy. However, we need to remember that there are times when a current attractor is no longer useful for the system’s survival as happens when the system is jarred out of its attractor basin. In such a case, the system would only survive if it transforms. Transformability is the capacity to create a fundamentally new system when conditions make the existing system untenable (Folke et al. 2001).

A key insight from resilience is that supply chains need to be designed to have the capacity to move from one configuration to the other, not so much that they have some optimal capacity where they remain resilient at all costs. As Gunderson and Holling (2002) observe, system resilience is not uniform across time, space,
and conditions. Rather, “a system can have a property that is robust to one set of perturbations and yet fragile for a different property and/or perturbation,” and thus “a system’s resilience expands and contracts.”

**Managerial Implications**

This research has several implications for managers. First, it is important for managers and supply chain actors to develop new mindsets about how they manage supply chains. There are at least three areas in which this mindset change is required: (1) the need to embrace volatility as a permanent feature of supply chains because these systems may never be at a standstill, but rather would be changing in nonlinear ways. Supply chain actors must be prepared for adaptation by embracing change and surprise. Indeed, strategic adaptation may be more important than planning for resilience alone. (2) Understanding the nature and impact of turbulence and (3) the way supply chain actors see crisis needs to change, crisis in complex adaptive systems often presents opportunities for renewal. Firms may be failing on these points. Sheffi (2005) observed that even after such wide-reaching disruptive events such as “9/11” and Hurricane Katrina, most companies are still not thinking systematically about managing supply chain risks and vulnerabilities.

Second, firms need to develop flexible, constantly evolving approaches to managing their supply networks. The unpredictable nature of complex adaptive systems creates an imperative for flexibility. Flexibility can come from design and management but more important must be reflected in the overall values and norms of supply chain members. This flexibility should extend to the intra-supply chain governance. Specifically, because supply networks can self-organize, managers need to remember that the system itself can respond to external shocks without a controlling actor. While not a call for a “hands off” approach, the lesson is that unnecessary intervention in the system may disrupt its own natural evolution.

Third and related is the need to foster complex adaptive systems thinking among stakeholders in the supply chain. Complexity thinking means accepting unpredictability and uncertainty as realities of supply chain evolution. Indeed, accepting uncertainty is a *sine qua non* for adaptive management. It also means actors need to understand the dynamics of the whole supply chain, not just focus on aspects of the system that they control. Walker and Salt (2006) observe that even though CAS thinking alone would not promote resilience, the recognition that such systems are based on connectivity, interdependence and uncertainty
Structuring and Managing Complex Adaptive Supply Chain Networks

may be a first critical step towards management actions that foster system resilience. Most of the ideas for managing CAS challenge some of our established ideas about supply chain management so it becomes necessary for leadership to help navigate the cognitive hurdles that may prevent the acceptance of novel ideas.

Finally, firms must develop their capacity for both individual, and organizational learning. The willingness to encourage experimentation and the search for new ways of doing things can prepare both the firm and individuals for constant change and evolution that is a reality of dynamic systems. Learning is a key aspect of adaptive management because it allows actors to explore various types of ideas to build solutions to the problems of managing complex systems.

Implications for Theory and Research

This research has several theoretical implications. First, since most of the existing knowledge on complex adaptive systems has roots in the physical sciences, it is important to delineate which concepts that apply CAS-based supply chains and use such knowledge in a way and manner that is consistent with its original application. More important, need to acknowledge, at the very least, the limits of their applicability. We need to recognize that despite some of the key parallels between supply chains and CAS, there are limits to how far we can apply some of the metaphors from the physical sciences to describe social phenomena and the extent to which we can generalize our findings. For example, self-organization in theory may best fit living systems (Gell-Mann, 2005) and be only partially applicable since people still need to design the operational framework and enabling environment for self-organization in such systems. Unlike living systems, humans are reflective and act purposefully (Walker et al. 2006). There is some speculation that developments in the application of intelligent machines in supply chains may one day allow us to model self-organization in supply chains to mirror self-organization in living systems (Wycisk et al. 2008). Concepts of adaptive governance and adaptive management may also have some limitations when it comes to their applicability to supply chains and so we need to explore the limiting conditions under which they may apply. For example, adaptive management assumes that policies and management interventions are tests of alternate hypotheses where failure may be temporarily accepted (Garmestani et al. 2009). However,
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businesses may have limited tolerance for experimentation and adaptive walks that bring the firm to lower levels of performance as even temporary dips in performance may lead to adverse stakeholder reaction.

Second, there are issues of how we design research to explore complex adaptive systems. Pathak et al. (2007) summarize the unique research design issues that confront the use of the CAS-based research lens. These include the system scale, unit of analysis, measurement and methodologies for studying complex supply chain networks. Emerging work has begun to use a variety of approaches to address some of these concerns. For example, Li et al. (2009) used modeling and simulation to study the adaptation of a supply network and these and similar tools can be used to study supply chains as CAS. Indeed, the mathematics of complex systems may also prove useful in this regard. For example graphical methods (Packard, Crutchfield, Farmer and Shaw, 1980), mathematical models (Hibbert and Wilkinson, 1994) and the mathematics of complex systems (Briggs and Peat, 1989) as well as qualitative designs can be used to study complex adaptive systems. For example, Holstrom and Hameri (1999) have reconstructed dynamical attractors to understand the long term dynamical behavior of supply chains using the Packard-Takens method (Takens, 1981) by reconstructing the demand attractor of a supply chain from single time series duplication using techniques for normalization of data. We can in principle construct a graph of the attractor with key variables as dimensions in a phase map. Qualitative designs may be particularly useful for gathering in-depth data on complex, dynamic systems. As Beer and Walton (1987: 344) argue that a "quantitative description may not be the best method for understanding a multi-causal phenomenon," qualitative research may be especially appropriate for studying dynamic complex systems because it allows the researchers flexibility in the sense that the researcher can adapt both the questions and focus of the research relatively more easily than in the case of most quantitative design. Researchers need to account for the multi-scale, multi-level nature of CAS in supply chains.

There is the need for further conceptual and practical evaluation of these new metaphors. Specifically, their validity to the supply chain literature to be strengthened. In that regard, some key research areas are worthy of further exploration and a few are mentioned here: (1) how do we know when systems cross one threshold to the other and are there predictive models we can use to determine when such
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Transitions will occur? (2) Will the adaptive capacity in supply chains ensure their resilience and (3) what do resilient supply chains look like and how can we measure them? Answers to this question certainly have important performance implications. There are presently some qualitative and quantitative tools for measuring resilience that need further development. For example, The Ohio State University has developed a framework, SCRAM, a survey tool based on risk and capability for measuring resilience. (4) How do individual actor capabilities including local resilience transfer into system-wide resilience? This last question is especially important to our understanding of cross-scale issues in complex adaptive systems. Finally, the propositional inventory generated here awaits empirical validation. Such a research program would have far-reaching implications for our understanding of not only how we manage supply chains but also would enhance our understanding of dynamical systems in general.

Conclusions

The key nature of complex adaptive systems is their unpredictability and nonlinear evolution. This means that we can neither always use the past as a guide for managing their future nor create a fail-proof blueprint for their management. Even with that limitation in mind, this paper makes several significant contributions to our understanding of supply chain management. We have advanced some key mechanisms for enhancing the design and governance of supply chain networks. We hope the research encourages further exploration of issues at the intersection of the design and management of CAS-based supply chain networks.

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Figure 1: Conceptual Model
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Supplier Learning in Supply Chain Competition

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This research uses the results of laboratory experiments in which subjects playing the role of suppliers compete for the business of a buyer outsourcing the manufacture of a commodity product. These results show significant differences with predictions from theory, and our research uses the Quantal Response Equilibrium (QRE) to consider whether bounded rationality and learning effects can offer some explanation for these variances.

The QRE framework was first introduced by McKelvey and Palfrey (1995). Based on the assumption that random errors occur in the decision-making process, the QRE considers that decisions will follow a probability distribution that are aimed at the highest expected payoffs, but factors influence those decisions away from the optimal. The QRE has been used frequently in prior research to model randomness in players’ (another term for experimental subjects) decisions, especially in behavioral economics, and studies have shown that the QRE can be a good predictor of non-optimal behavior in many game theoretic settings (e.g., Anderson et al. 1998&2001; Capra et al. 1999; Fey et al. 1996; Goeree and Holt 2000; Goeree et al. 2002; Ho and Zhang 2008; Lim and Ho 2007). In recent years, researchers have brought the QRE framework to operations management, and although a relatively unexplored application, it has been used successfully in several different studies (e.g., Blake and Elahi 2015, Chen et al. 2012, Chen and Zhao 2015, Davis et al. 2013, Lim and Ho 2007, Su 2008).

In one example from the operations management literature, Chen et al. (2012) examine a competition between retailers for the limited capacity of a common supplier. They investigate the decisions of the retailers experimentally, and by comparing the results with theory find that the subjects’ average order is lower than what the Nash equilibrium predicts. They explain that in the real world, the two strong assumptions that underlie the Nash equilibrium, which are that every player is a perfect optimizer with perfect knowledge of their competitors’ decision models, do not hold. To determine whether bounded rationality can lead subjects to make random errors in their decisions, they use the QRE and find that players in a supply chain competition become more rational through repeated decisions, and that their
decisions approach theoretical predictions as the experiment proceeds. Their model proposes a bounded rationality parameter ($\beta$) as a function of time, as shown in the following equation

$$\beta(t) = \gamma + (\alpha - \gamma) \times e^{-\delta \times (t-1)}$$

in which $\alpha$ is the initial $\beta$, $\gamma$ is the eventual $\beta$, $\delta$ is the rate of learning, and $t$ is round of the experiment.

In another experimental study, Blake and Elahi (2015) study the competition of two suppliers for the demand of a single buyer, a common scenario in the real world. They find that in most cases, suppliers’ decisions are significantly different than the Nash equilibrium. The authors use an extended version of QRE method to quantify the impact of different factors on decisions of the players under different competition setups, and our research extends their results by examining bounded rationality and the effects of learning.

Experimental research has looked trends in players’ decisions over time to investigate learning effects, but not in the setting we are considering. For example, among prior studies using this approach is one by Chen and Zhao (2015), who study a capacity allocation game with two identical retailers and one supplier who uses a proportional allocation scheme to allocate a limited capacity. They define a critical fractile factor to reflect the profit margin of each unit allocated to the retailers, and by using it to investigate players’ decisions, find a learning pattern to exist. In another study, Song and Zhao (2016) study strategic customer behavior in a monopolistic seller system. The authors investigate customers’ bounded rationality behavior by considering the QRE as a behavioral model, and also find a learning effect to be present.

In our study, we are using experimental results from the supply chain setup presented in Elahi (2013), which consists of single buyer who outsources the production of a product among $N$ potential make-to-stock suppliers. Demand from the buyer is generated according to a Poisson process, and is allocated proportionally to suppliers based on the competition criteria. Each experiment consists of 30 independent rounds in which subjects make a decision.

We are applying the QRE framework to the data gathered from these prior experiments. Our model of players’ decisions considers a bounded rationality parameter ($\beta$) as a function of time, and we are determining the parameters for this equation which best fit the experimental data.

By developing this model from the QRE framework, we will be able to evaluate learning effects and whether they vary under different scenarios of competition. A better understanding of the decision-making
process, and how it is influenced by bounded rationality and learning effects, can not only help buyers better design their outsourcing plans and structure criteria for outsourcing among suppliers, but also help suppliers make more rational decisions.

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Supply Chain Integration (SCI) – Supply Chain Agility (SCA) Dilemma:
a New Model and Interfaces with Innovation and Sustainability for Research and Teaching

Northeast Decision Sciences Institute Conference 2017
Springfield, MA
March 22-25, 2017

Introduction

Seemingly opposing dualities among various strategies that firms can pursue may create operational tensions (Adler et al. 2009) that exist between short-term efficiency and long-term adaptability (Abernathy 1978; i.e. productivity dilemma). These seemingly irreconcilable tensions are what managers must routinely deal with, which Adler et al. (2009) says creates a dilemma. In the context of operations and supply chain management, the extant concepts of integration and agility form a duality that organizations could nurture for increasing short-term efficiency and long-term adaptability. However an operational dilemma seem to surface when organizations work toward implementing both, supply chain integration (SCI) and supply chain agility (SCA) activities simultaneously. This study posits that the supply chain activities that lead to greater SCI and SCA also create a dilemma which not only is applicable to the literature (academics), but also to industry (practitioners). We find that better understanding of this dilemma, and SCI, and SCA can lead to greater firm benefits and performance of the supply chain.
Rationale of the SCI-SCA Dilemma

Why important?

Productivity dilemma (Abernathy 1978) was defined almost four decades ago and recently, Adler et al. (2009) revisited this phenomenon and suggested that “Organizations often find themselves torn between contradictory and conflicting goals. The productivity dilemma highlights the tension between a particular pair of widely held goals: efficiency and adaptability.” In this study, we propose the SCI vis-à-vis SCA dilemma that is similar to the basic idea of contradictory and conflicting goals on one hand but different than the particular duality of efficiency and adaptability on the other hand.

From a practitioner’s vantage point, the Pareto principle may suggest that most SCI activities yield to increase in short-term efficiency and most of SCA activities result in long-term adaptability gains. However, an experienced practitioner’s exploratory comparison would result in discovery of a clear distinction between the two dualities. While this may be the case, the overlap is also undeniable. More importantly, the existence of the well-established SCI and SCA constructs in academic literature offers a great opportunity for at least establishing a scholarly linkage with industry and practitioners in following ways:

- Ultimately, the definition of the proposed SCI – SCA dilemma is not assumed nor implied.
- The proposed SCI – SCA dilemma is based on definitions that are within the context of supply chain, both in academia as well as practice.
The proposed SCI – SCA dilemma addresses the managerial implication gap of supporting the performance improvement claims for each of these two constructs at the simultaneously.

*Why innovative?*

Examining the insight of the proposed SCI – SCA dilemma, this should benefit the practitioners for better managing the tensions between SCI and SCA. While these directly contribute to productivity dilemma and the operations and supply chain management discipline, additionally, theoretical and managerial discussions could offer avenues for expanding the contributions, exploring potential interfaces, and elaborating on limitations. The proposed SCI – SCA dilemma also benefits to the society such that besides addressing the efficacy of the humanitarian supply chains (HSC) and sustainable supply chains (SSC), since better measurement of the proposed SCI – SCA dilemma would lead to better management and performance of the supply chains, greater efficiencies and further innovation should be expected in any given supply chain.

*To whom the proposed SCI – SCA dilemma is speaking?*

Scholars Interested in the Productivity Dilemma and SCM Scholars: Revisiting the productivity dilemma in their article, Adler et al. (2009) conclude that deliberately allowing the disruption or perturbation of the organizational balance through proactively embracing the tension and conflict could be a way to sustain ‘both efficient practice and innovation’. We posit that this prescription could be operationalized via the help of SCI and SCA while encompassing a broader and end-to-end supply chain management notion.

Adler et al. (2009) help us explain the tension that exists between short-term efficiency and long-term adaptability (Abernathy, 1978). The irreconcilable tension seems to be what managers must
manage every day. Perceived as more than a dilemma, supply chains are required to be simultaneously efficient and also innovative (Adler et al., 2009, p.101). In response, we propose that if the firms manage the proposed dilemma well, the interaction between SCI and SCA would offer added synergies.

**Practitioners:** While the proposed SCI – SCA dilemma is new in the supply chain literature, extant literature doesn’t provide a proper definition that also offers a generally accepted measure of such a dilemma. Herein this study, knowing that today’s digital mode may become tomorrow’s analog mode (i.e. Gooley, 2016; SCEC 2016), we investigate the main idea behind these dual-strategy approaches which we postulate can be explained within the proposed SCI – SCA dilemma. We also provide a solid foundation for a way of grounding the productivity dilemma that will inspire further work in this topic.

**Strategy scholars:** We propose the existence of greater benefits to firm performance stemming from nurturing and managing the proposed SCI – SCA dilemma in lieu of a one-sided, either well-integrated or an agile supply chain strategy. This proposal puts us on a quest for investigation of best performing supply chains in the face of continuous change which was previously investigated from different perspectives (i.e. by Porter, 1996; Lee, 2004).

**Public at large:** The duality of being well-integrated but also agile at the same time can be operationalized in any context.

**Value of the SCI – SCA dilemma**

To date, there hasn’t been much scholarly focus on SCI – SCA dilemma from SCM perspective. Also, bringing the productivity dilemma and the SCI – SCA dilemma together is innovative in the literature. Moreover, this approach is highly relevant to everyday business operations and
strategy. Consensus on simultaneous existence of SCI and SCA would spur further related works which is what we intend to promote and develop with a series of studies related to this dilemma. These studies would also enable effective teaching in all settings and also collaboration with other disciplines but most importantly, the industry.

References


Title: SWOT as a Constructive Predictor for Business Success of SMEs: A Case Study

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ABSTRACT
Sustaining and growing a profitable business is challenging. Business in today’s market needs to be understood, classified, and a strategic management process needs to be applied to improve the likelihood of success. Business success is defined by the company in terms of what motivates, drives and sustains the organization. The proper predictor tools to be utilized are those that engage the Operating Management Team, cover a proper scope of evaluation and provide a pathway to executing a game-plan for success. SWOT is such a tool that identifies the critical Strength, Weakness, Opportunities and Threat factors that need to be addressed to drive business success. This paper presents a case study that explores how to identify and use the SWOT tool in a technically-oriented Small Medium Enterprises (SME) that will grow the company in terms of revenue.

KEY WORDS
Business Success, Small Medium Enterprises (SMEs), Strategic Technology Planning, SWOT (Strengths Weaknesses Opportunities Strengths), Technology Management.

INTRODUCTION
Modern business improvement theory is broad and varied. Techniques applied to develop a strategic technology plan follow a methodical approach. The application of such techniques is as important as their selection. Experience is a key factor, but understanding human dynamic and motivation are equally important (Kerr, Farrukh, Phaal, & Probert, 2013). Tools such as Porter’s Five Force, SWOT, Competitive Matrix, EFE/IFE, and Boston Matrix are among the popular techniques that are commonly used to monitor, evaluate and enhance business practice. The best possible outcome for business success is defined by the company’s vision and sustainable
practices. This paper presents a case study that explores how to identify and use a tool, SWOT, in a technically-oriented SME that was the predicting tool that became the foundation for its Strategic Road Map. This Map supported its Vision and Mission statement development and assisted in creating a Business plan that if executed properly, would meet their desired revenue growth plan of 200 percent in five years. Given that technology development is a time-sensitive process, this often necessitates the use of a tool that can be properly executed within a given time-frame. The tool is best used to establish current and future success while assuring a historic profile for reference.

Multiple factors influence business results and can be categorized as either quantitative or qualitative. A review of techniques and practical application has been applied. An optimal result should be measured, adjusted frequently and account for human interaction and change. The use of well-known strategic tools was evaluated with the use of SWOT (Strength, Weakness, Opportunities and Threats) as a specific emphasis. The SWOT tool has been in use for over 25 years with subsequent additional tools developed. Indeed, the process of evaluating an organization’s Strength, Weaknesses, Opportunities and Threats has proven to be an effective tool to align and focus a business. Strategically, Technology Companies need to understand their SWOT, and then use this information for competitive advantage and growth.

SWOT has been used successfully in many cases. The evaluation confirms that SWOT is an effective business tool. It’s simplicity of use and extraction of critically significant business factors for the company, allows proper engagement, usage and support. Thus, SWOT can be applied successfully to SMEs despite issues such as limited resources, available time, and moderate business analytical business competencies.

**LITERATURE REVIEW**

Technology management is a specific skillset that applies pertinent management with technical competency. This is particularly difficult in SMEs where these skillsets may be limited or lacking due to the company’s size. Therefore, planning becomes paramount to the continued success of these SMEs as it sets the stage for resource alignment, prioritization of critical factors that drive future success, and an execution plan that is closely monitored and managed. It has been stated that at times, strategic planning tools may not be appropriately applied, and the end
result not effective (Jarzabkowski & Kaplan, 2015). However, a desired end-result for business success should always be considered, and as such, the best tools are those that can be applied within the company’s framework and culture. Linking technology management to the business strategy and strategic planning process is logical and is best accomplished by following a methodical approach. This can be applied to international as well as domestic companies as the concept is unchanged (Wei-wei, Da-peng, Yu, & Yang, 2010). It has been stated that Strategic Planning may not be appropriate in today’s rapidly evolving Technology Management companies. The inference is that it may be too slow or incapable of keeping pace with the changing need to be rapidly adaptive to the competitive landscape. The lack of planning can lead to misdirection and mismanagement, so it is as necessary as ever to implement a strategic road map and plan in SMEs (Kukreja, 2013).

**METHODS**


SWOT tool has the following description of each category:

<table>
<thead>
<tr>
<th>STRENGTHS</th>
<th>WEAKNESSES</th>
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<tbody>
<tr>
<td>Internal factors that identify strengths of an organization</td>
<td>Internal factors that identify weaknesses in an organization</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>OPPORTUNITIES</th>
<th>THREATS</th>
</tr>
</thead>
<tbody>
<tr>
<td>External factors that identify opportunities for an organization</td>
<td>External factors that threaten an organization’s success</td>
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</tbody>
</table>

SWOT reveals critical factors that if addressed properly, can be necessary to the development of a strategic plan. Other critical aspects for a strategic plan include the determination of a Vision and Mission for the organization. (Giannotte, N. 2010).
Vision defines what an organization stands for or aspires to become?

Mission defines an organization’s business?

**CASE STUDY**

A case study was performed on a small technical design company (SME) with a goal to determine how to grow the company’s revenue. The use of several business evaluation tools was applied to accomplish this growth objective. The company’s Operating Team (referred to as The Team) was assembled and interviewed to learn about their assessment of the company’s performance. Based on their feedback, it was determined that the company would benefit by identifying and defining the critical factors that will have an impact on the company’s revenue. It was also determined that the proper application of these critical factors for future growth must include a strategic plan that aligns with the company’s Vision and Mission statements. Results from the interview shed light on the fact that the company has been in business for more than 50 years and has seen considerable growth despite a downturn in revenue after the recession of 2008. Presently, The Team was confronted with more business opportunities than it had resources to handle. Therefore, a proper business assessment tool that employs a proven technique was deemed necessary for the team. As mentioned above, while multiple tools were investigated, the SWOT tool stood out as most suitable for The Team and the chosen SME. It required cross-functional collaboration, was efficient to use and interpret and utilized the collective knowledge of the Team.

The Team was trained on how to use the SWOT tool and quickly assembled. They conducted multiple sessions and based on results, arrived at a conclusion under the guidance of their President. SWOT tool results provided insight and indication of Strengths, Weaknesses, Opportunities and Threats to their company. These insights are the factors that influence the company’s growth and form the focal point for future planning and prioritized action for improvement with the ultimate objective of accomplishing business success. Results were as follows:
Strengths

- Advanced manufacturing capability
- Problem solving ability
- Strong and experienced management team
- Tenacity and synergism of the company
- Ability of assembling technologies together
- Extensive capabilities including design, prototype, qualify, procure, manufacture, test, inventory, deliver, warrant and repair
- Wide product and service variety
- State of the Art printed circuit board capabilities
- Reliable brand names with proven past performances

Weaknesses

- Organizational structure is too dependent on the CEO
- Lack of customer diversification
- Weak external sales team
- Age of management team
- State of the Art Production line is limited to one line
- Lack of 3D Xray
- Automated Optical Inspection needs upgrade
- Weak RF equipment and experience
- Limited financial ability
- Efficiency of instituting and maintaining quality programs
Opportunities

- Management keeps one company and one focus, and things outside are separate company
  Turnkey and RF products
- Different industry channels such as electronics industry, defense industry, medical industry
- UAV/UAS Unmanned Vehicles
- Expand 3D printing
- Expand trade shows
- Expand sales territory
- Identify focus of capabilities by customer needs

Threats

- Insufficient cash flow due to customer changes, push outs, and delays
- Competition and pricing pressures
- High volume and low margin products
- High risk of lack of market being served
- Knowledge of potential customer solvency and capabilities
- Lack of knowledge of markets served
- Lack of viable leads
- Jading the customers due to salesman turnover

Another mode for SWOT information analysis is to group results in a matrix. This becomes an efficient process where internal Strengths and Weaknesses and external Opportunities and Threats can be grouped and evaluated. The boxes that become the strategies; ST, SO, WO, WT are the basis for business planning, operating focal points and actions, that if properly executed, foster business success.
**Summary of SWOT Matrix Strategies Improvement Recommendations:**

- **Strength and Opportunities (SO) Strategies:** Use nimble entrepreneurial engineering problem solving skills.

- **Strength and Threats (ST) Strategies:** Develop priority marketing plan and enhance marketing skills.

- **Weakness and Opportunities (WO):** Develop sales team and broaden critical function skills/resources/priority

- **Weakness and Threats (WT):** Acquire market knowledge, enhance GM/operating team, hire dedicated technical manager
Company evaluation required a series of events that initiated with a company overview, a company tour, a series of discussions, various training sessions including a SWOT tutorial, and culminated in a SWOT assessment. The SWOT matrix and files became the basis for the Strategic Planning Road Map:

- Develop Vision Statement
- Develop Mission Statement
- Develop Marketing/Business/Strategic Plan (in that order)
  - Determine Market Focus
  - Determine Financial Targets
  - Create Human Resource Plan
    - Develop requirements; attain and retain
    - Assure on-going succession planning
- Implement Plan Actions
CONCLUSIONS

SWOT is a business predictor tool, that when used with the proper cross-functional team approach, is very effective. It exploits weaknesses and threats while highlighting strengths and weaknesses. The first stage to executing any strategic plan is the awareness of your business, and SWOT creates that awareness. SWOT is a technique that will unveil the critical aspects of your business and identify areas to improve or modify. A strategic plan can be developed that will provide guidance for future business success. Within the plan, a typical starting point is to create a Vision and Mission statement. This will guide future direction, assure that the focus is consistent and assist with priority direction of the business.

The case study SME determined its primary definition of success as desiring to double its sales within a five year period. The Strategic Road Map that was developed used the SWOT technique as a methodology to determine what was critical to the business to meet its growth target.
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Abstract

During the period of the global financial crisis (2008-2012), lending institutes including banks became more conservative in issuing new commercial loans. For many companies, this meant difficulties in finding credits for their working capital needs, procurement, and long-term investments. As a result, it has become vital for companies to use operational measures to reduce their dependency on external financing through banks. One of the ways to reduce their need in credit is through delaying trade credit payments to their suppliers (sellers). However, sellers may have difficulties in adjusting to any additional delays in payments. In this study, we are looking into how to determine potential problematic buyers in an international setting. We do examine a relatively large size of data (1667 firms) across six European/Eurasian countries during financial crises of the late 2000s, and bring managerial insights. Some of these insights include: lower internal funding ratios of firms signal of future trade credit/bank credit needs, delayed payments and drop in sales additionally determine future TC/BC needs, trade credit and internal funding ratios differ significantly from one country to another, whereas bank credit ratios differ less significantly, and finally firm size and industry are less significant factors in trade credit ratio compared to the country firm is located. This study is unique in sense that the focus is on buyer selection not on supplier selection, while bringing insights on trade credit in supply chain management.

Keywords: Trade Credit, Buyer Financing, Supply Chain Management, Global Financial Crisis.

Highlights:

- Lower internal funding ratios of firms signal of future trade credit/bank credit needs
- Delayed payments and drop in sales additionally determine future TC/BC needs.
- Trade credit and internal funding ratios differ significantly from one country to another
- Whereas bank credit ratios differ less significantly.
- Firm size and industry are less significant factors in trade credit ratio compared to country
1. Introduction

During the period of the global financial crisis (2008-2012), lending institutes including banks became more conservative in issuing any new commercial loans. This meant for many companies difficulties in finding credits for their working capital needs, procurement, and long-term investments. As a result, it has become vital for companies to use operational measures to reduce their dependency on external financing through banks. One of the ways to reduce their need in credit is through delaying trade credits payments to their suppliers. This practice allows buyers to maintain their financial solvency and keep vital cash on hand for a longer time during harsh financial environment. Goals of this paper are first to examine trade credit changes during the period of the late 2000s financial crisis using six emerging countries as case studies and secondly to find out what factors were significant in predicting additional delays in trade credit payments. From suppliers’ perspective, it is important to know under which conditions a buyer is likely to ask for additional trade credit or extension of the payment period. This will allow better management of trade credit risk of sellers.

The term “Trade Credit” (TC) here refers to the amount of delayed payments between two business entities (B2B). Trade Credit (TC) is often a short-term loan, which a supplier offers to its buyers, instead of the immediate exchange between cash and products. The common terminology of TC is Net 30, Net 60, and Net D, which means the buyer has agreed to make payment in 30, 60, or D days. Buyers’ main motives for delaying payments are to reduce the insolvency risk in case of nonpayment or delayed payments of their own customers, to ensure easier and proper handling of unsold or returned goods by their supplier, or to have an additional buffer against ongoing or potential financial stress. There is insolvency risk when a buyer who is an intermediate between the final customer and suppliers decides to make a payment before receiving payment from the final customer.

Rajan and Zingales (1995) pointed out that trade credit accounts comprise a large percentage of total assets firms hold. During the early 1990s, 17.8% of total assets of all American firms were in the form of trade credits (Bougheas, 2009). Similarly, in certain European countries, trade credit accounts have a much higher rate at 70% of a total short-term debt and up to 55% of total credit received by firms made up trade credit (Gurariglia & Mateut, 2006; Kohler et al., 2000). Trade credit is an additionally
important source of funds for firms in emerging economies with weak, insufficient, and/or highly risk-averse banking systems (Ge & Qiu, 2007).

Many of the countries of Eastern Europe are emerging economies and are highly integrated into the larger European markets. This region is one of the most affected areas of the global crisis of the late 2000s, is certainly a good candidate for research in examining trade credit in the face of new global realities. In order to have a large-scale analysis on trade credit changes and structure during the recent recession, a secondary dataset collected by the World Bank from some of these Eastern European countries on firm and industry level about trade credit during the recent recession will be used. In this paper, the focus is to further understand the changes in trade credit during financial crises based on following research questions:

- Does being in a particular industry, having certain company’s size or located in certain country matter in trade credit usage compared to other sources of funding?
- Which of these factors are more important in predicting increase in in trade credit needs?

The paper continues as follows: first, there is a short discussion on trade credit in SCs followed by a review of theories related to trade credit; second, there is a section for data description and initial analysis; third, empirical results are discussed; and lastly, limitations of the current study and future research potential are discussed.

2. Theory

In managing working capital, firms use funds from credit institutions/banks, internal funds, and trade credit from suppliers. Payments between buyers and supplier can be done before, concurrently, or after the physical delivery of the product/service. The amount of delayed payment determines the size of the trade credit from supplier to buyer. Supplier carries the risk of potential nonpayment or delayed payment while offering this trade credit. On the other hand, by paying earlier; a buyer carries the risk of imperfect, returned, and unsold products because the seller has less incentive to accept them back.

Today's highly competitive business environment compels suppliers to offer trade credits in order to grow or maintain their market share and develop long-term relationships with their customers. Hence, trade credit (TC) decisions can be suboptimal and risky under the pressure of "closing the deal" and not losing the customer, which can jeopardize the very existence of the supplier. Suppliers may have to offer trade
credit to firms that are under financial distress and riskier in order to sell their products. Financial institutions and investors, on the other hand, prefer to lend to larger, mature firms with better credit ratings (Nilsen, 2002). In understanding why trade credit does exist, the perspectives and reasons of both suppliers who offer and buyers who accept need to be discussed.

On the buyer’s side, firms use TC when their alternative sources of financing are limited or less attractive (Alphonse et al., 2004; Danielson & Scott, 2004; Deloof & Jegers, 1999; Niskanen, 2006; Petersen & Rajan, 1994). Trade credit can be cheaper than using bank credit and internal funds if the transaction cost between trade credit partners is lower compared to the one between the firm and bank. In general, TC helps firm in managing working cash by reducing the potential cash inflow and outflow mismatches (Schwartz, 1974). By using trade credit, buyers achieve a more flexible cash outflow in terms of time and amount of payment to suppliers. Additionally, suppliers share certain business risks with their buyers (Chen et al., 2010; Shah & Singh, 2001). Such risks include nonpayment and delayed payment risk of the final customers of buyers. By delaying the payments to suppliers, buyers also have additional leverage in returning unsold or imperfect products. Finally, TC helps in developing long-term relationships between suppliers and buyers. Compared to penalties for nonpayment or delayed payments to financial institutions, penalties in trade-credit agreements can be less severe and destructive since many suppliers prefer long-term relationships with same buyers (Fabbri & Klapper, 2009).

From the supplier’s perspective, offering competitive trade credit attracts more potential buyers. Often, in order to secure more orders, suppliers offer buyers trade credit with substantially better conditions than financial institutions do (Chen et al., 2010). In addition, to keep up with competition, a supplier can obtain several advantages by offering trade credit (Petersen & Rajan, 1997). These benefits include:

- reducing informational asymmetries (Blais & Gollier, 1997; Smith, 1987)
- ability to offer price discrimination (Brennan et al., 1988)
- developing long-term relationships
- monitoring advantages (Jain, 2001; Mateut et al., 2006)
- increasing product quality (Lee & Stove, 1993; Long et al., 1993)
- potential leverage for opportunistic behavior (Burkart & Ellingsen, 2004).
Trade-credit agreements allow suppliers to acquire valuable information about their buyers’ financial health. For instance, if a buyer suddenly starts delaying payments or seeks for extensions, this may indicate potential problems in the financial health of the firm. For future deliveries, a supplier can ask for shorter payment periods, increased initial payment or collateral, or simply request full payment in advance. TC offers an additional way of price discrimination instead of simple discounts. Firms can negotiate on the length of trade credit instead of the product price. By offering TC, suppliers have the chance to develop long-term relationships with their buyers. In turn, this helps suppliers get better feedback about their products which would give them the opportunity to increase quality to a competitive level, to monitor advantages, make necessary adjustments in price, and bring new profitable features to a larger market. Suppliers can use trade credit to acquire invaluable information about the financial health of buyers, their customers, profit margins etc. With the additional leverage of unpaid debt, suppliers can force buyers into bankruptcy for a hostile takeover should the opportunity arise.

### 3. Calculation

#### 3.1 Data

Part of the data in this paper is drawn from a survey conducted by the World Bank in 2010. It consists of responses from individual firms from the following countries: Bulgaria, Hungary, Kazakhstan, Latvia, Romania and Turkey. These countries are middle- to low-income emerging economies located in Eastern Europe. All of these counties have been using their local currencies unlike many developed European countries that use the Euro. Currencies of these countries are Bulgarian Lev, Hungarian Forint, Kazakhstani Tenge, Latvian Lats, Romanian Leu, and Turkish Lira. In addition, these countries follow relatively independent monetary policies but economically are significantly interconnected with the larger European Market. Table 1 shows the number of firms responded and accepted as fit to the survey conducted:

<table>
<thead>
<tr>
<th>Country</th>
<th>Number of Firms Responded</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bulgaria</td>
<td>152</td>
</tr>
<tr>
<td>Hungary</td>
<td>151</td>
</tr>
<tr>
<td>Kazakhstan</td>
<td>233</td>
</tr>
<tr>
<td>Latvia</td>
<td>221</td>
</tr>
<tr>
<td>Romania</td>
<td>304</td>
</tr>
<tr>
<td>Turkey</td>
<td>606</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>1,667</strong></td>
</tr>
</tbody>
</table>
Table 1: Countries represented in the study

The total number of firms is well within the acceptable number for a large study. By being a significantly larger economy, Turkey has understandably a great number of companies responded to the survey. Figure 1 shows the GDP amount of these countries in 2011.

![2011 GDP of countries in question](image)

Turkey's GDP is larger than all of these countries' GDP combined and stands at around 750 billion US dollars. Romania and Kazakhstan have similar sized economies, with GDP around 180 billion US dollars, followed by Hungary with 140 billion US dollars. Bulgaria and Latvia are smaller economies with 53 and 28 billion US dollar GDPs, respectively.

The survey data include information for individual firms located in the aforementioned countries. These firms are grouped into small (fewer than 19 employees), medium (20-99 employees) and large (greater than 100 employees). The next table shows the breakdown of companies responded in terms of firm size across all countries in the study.

<table>
<thead>
<tr>
<th>Firm Size</th>
<th>Number of Firms Responding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Small ≤19</td>
<td>559</td>
</tr>
<tr>
<td>Medium ≥20 and ≤99</td>
<td>610</td>
</tr>
<tr>
<td>Large ≥100</td>
<td>498</td>
</tr>
</tbody>
</table>

Table 2: The number of firms for each size category

The aggregate data (Table 2) are equally distributed among small, medium and large sizes in terms of the number of firms in each bracket.
Next, data are divided in terms of industries firms operate. Industries are grouped into 17 industry-specific groups, including retail, manufacturing, food, wholesale, construction, textiles, garments, non-metallic mineral products, chemicals, transportation, metal products, machinery and equipment, plastics and rubber, hotel and restaurants, basic metals, IT, and electronics. The following table shows the number of firms responded to the survey grouped by the industry they are in.

<table>
<thead>
<tr>
<th>Industry</th>
<th>Number of Firms Responding</th>
</tr>
</thead>
<tbody>
<tr>
<td>Retail</td>
<td>380</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>158</td>
</tr>
<tr>
<td>Food</td>
<td>157</td>
</tr>
<tr>
<td>Wholesale</td>
<td>142</td>
</tr>
<tr>
<td>Construction</td>
<td>115</td>
</tr>
<tr>
<td>Textiles</td>
<td>105</td>
</tr>
<tr>
<td>Garments</td>
<td>101</td>
</tr>
<tr>
<td>Non-Metallic Mineral Products</td>
<td>81</td>
</tr>
<tr>
<td>Chemicals</td>
<td>73</td>
</tr>
<tr>
<td>Transport Section</td>
<td>70</td>
</tr>
<tr>
<td>Metal Products</td>
<td>64</td>
</tr>
<tr>
<td>Other Services</td>
<td>54</td>
</tr>
<tr>
<td>Machinery and Equipment</td>
<td>45</td>
</tr>
<tr>
<td>Plastics and Rubber</td>
<td>35</td>
</tr>
<tr>
<td>Hotel And Restaurants</td>
<td>29</td>
</tr>
<tr>
<td>Basic Metals</td>
<td>22</td>
</tr>
<tr>
<td>IT</td>
<td>19</td>
</tr>
<tr>
<td>Electronics</td>
<td>17</td>
</tr>
</tbody>
</table>

Table 3: The number of firms by industry type

3.2 Effects of the Late 2000s Crisis

The global financial crisis of the late 2000s originated in the United States at the end of 2008. Later problems progressed across the globe in both developed and emerging economies. The exact timing of the start and end for each country in the survey is somewhat different from each other. However, all of the survey data countries had significant financial problems during the common time period of 2009 to 2010.

First, the effects of the financial crisis in the late 2000s in terms of industry, country, and firm’s size are discussed in this section. Figure 2 shows the number of firms reported sales lost in 2010 (peak period of the financial crisis) compared to their sales in 2009.
From Figure 2, it can be seen that all countries were affected by the global crisis. However, Turkey and Kazakhstan had better results in terms of firm sales than Bulgaria, Hungary, Latvia and Romania. According to this study, Latvia with 72%, had the biggest number of companies reported a loss in sales compared to 2009. Such high percentage of sale drops is quite significant. Next the figure compares the GDP during the financial crisis and before (the reference year is 2008) for these countries (Figure 3).

GDP numbers are from the World Bank database in terms of US dollars. It is noteworthy that all countries in the study had their GDP drop in 2008, with a range from 6.28% for Bulgaria to 23.15% for Latvia. By 2011, only Turkey, Bulgaria and Kazakhstan had recovered to their pre-crisis year of 2008. Kazakhstan's recovery is definitely more remarkable compared to the other countries. In the following
figure (Figure 4), the effects of the financial crisis on the average GDP growth in study countries are demonstrated.

![The Effects of the Financial Crisis on Average GDP Growth](image)

**Figure 4: The effects of the financial crisis on average GDP growth**

When comparing the average GDP growth rates of 2009-2011 with the averages of 2000-2008, a significant change for each country can be observed. Rates range from -2.76% for Latvia to -0.96% for Kazakhstan. Furthermore, there are remarkable differences between countries in terms of growth rates and growth rate changes. The reasons why a certain economy had a better response are not covered in this paper. Next, firm sizes and percentage of firms with decreased sales is shown (Figure 5).

![Percentage of Firms with Decreased Sales in 2010 compared to 2009](image)

**Figure 5: Percentage of firms with decreased sales in 2010 compared to 2009 (firm size)**

These are aggregate data across the aforementioned countries. It is interesting to notice that large firms have less percentage of decreased sales compared to medium- and small-sized companies. Only 48% of the large firms had decreased sales, while 62% of the small firms had decreased sales. Next, here is the data in terms of industry.
It is interesting to see that hotels and restaurants, retail, electronics, construction are the leading sectors in percentage of firms with decreased sales. It can be caused by the fact that customers are more likely to cut first their less immediate needs such as hotels and restaurants.

### Variables of Interest

In order to investigate the impact of the global financial crisis on trade credit, firm financial health in the countries surveyed, a set of macro (country-wise) and micro level (individual firms) data is used. In terms of macro level, there are two measures in the study to understand the extent of the financial crisis. Both of them are supplied from the World Bank:

- GDP, the gross domestic product for six countries in the years of 1999-2011
- Credit lend through domestic banks in terms of the percentage of GDP in the years 1999-2011

In terms of micro level, the following firm level measures are supplied by the World Bank survey or calculated during this study:

- Demographics of companies in the study
  - Location(country)
  - Size
  - Industry

- Working capital ratio measures:
  - Working capital ratio financed from internal funds

- Pre-crisis ratio

<table>
<thead>
<tr>
<th>Industry</th>
<th>Percentage of Firms with Decreasing Sales</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hotels and Restaurants</td>
<td>78.57%</td>
</tr>
<tr>
<td>Retail</td>
<td>70.48%</td>
</tr>
<tr>
<td>Electronics</td>
<td>64.71%</td>
</tr>
<tr>
<td>Construction</td>
<td>59.29%</td>
</tr>
<tr>
<td>Transportation</td>
<td>58.82%</td>
</tr>
<tr>
<td>Other Services</td>
<td>57.41%</td>
</tr>
<tr>
<td>Machinery And Equipment</td>
<td>55.56%</td>
</tr>
<tr>
<td>Other Manufacturing</td>
<td>55.41%</td>
</tr>
<tr>
<td>Plastics and Rubber</td>
<td>54.29%</td>
</tr>
<tr>
<td>Wholesale</td>
<td></td>
</tr>
<tr>
<td>Nonmetallic Mineral Products</td>
<td>50.63%</td>
</tr>
<tr>
<td>Basic Metals</td>
<td>50.00%</td>
</tr>
<tr>
<td>Fabricate Metal Products</td>
<td>50.00%</td>
</tr>
<tr>
<td>Garments</td>
<td>48.98%</td>
</tr>
<tr>
<td>Food</td>
<td>47.40%</td>
</tr>
<tr>
<td>IT</td>
<td>42.11%</td>
</tr>
<tr>
<td>Chemicals</td>
<td>38.36%</td>
</tr>
<tr>
<td>Textiles</td>
<td>36.54%</td>
</tr>
</tbody>
</table>

Table 4: Percentage of firms with decreased sales in 2010 compared to 2009 (industry-wise)
• During the survey ratio
  o Financed from bank credits (only during the survey)
  o Financed from trade credit (only during the survey)

• Change in sales during the survey compared to pre-crisis

• Financial health / insolvency measures
  o Establishment overdue on its obligations to any financial institution in the last three months (Yes or No)
  o Establishment filed for reorganization (readjustment of a firm's debt and capital structure after a bankruptcy or receivership order) in the last three months (Yes or No)
  o Establishment was insolvent in the last three months
  o Establishment filed for bankruptcy during the last three months
  o Establishment applied for direct state aid in the last three months

• Delays in Payments measures
  o Establishment have delays in payments for more than one week in one of the following:
    ▪ Taxes, excluding payroll taxes
    ▪ Payroll tax and social security
    ▪ Suppliers

3.4 Model

In this paper, two layers of models are used. In the first layer, investigation is on whether or not being in certain country; industry and size make a difference in working capital funding percentage: trade credit, bank credit, and internal funding. TC ratio is the prime focus on this study. Location includes six countries of the survey, Bulgaria, Hungary, Kazakhstan, Latvia, Romania, and Turkey. Industry includes sixteen categories defined in the study. Size includes small, medium and large. All of these variables are categorical variables.
In the general model, the main focus is again trade-credit ratio. Here it is important to notice: this study is eventually a time series event study based on a secondary data set. First, here is the drawing for the general model. Letter h represents predictor-response relationships.

Because there is no control over the type of questions in the survey in this study, only some of the variables can be used to test the difference that a financial crisis brings to trade credit and related firm financial health. In this study, the global financial crisis has three effects: drop in sales, and drop in growth of credit lend via domestic banks. In addition to these variables, there three response variables in the study: the trade-credit ratio after crisis, bank credit ratio after crisis, and delayed payments/financial insolvency. Delayed payments/financial insolvency is a binary measure where one represents problems in this area and zero represents company without problems when the survey was conducted. All three occur after the crisis started. Predictor variables for them are drop in sales, pre-crisis internal funding.
ratio, and drop in growth of credit lend via domestic banks. All of these predictor variables precede response variables they are linked to.

3.5 Hypotheses and Methodology

First, whether or not trade credit, bank credit, and internal funding ratios are influenced/determined by the demographics of firms is investigated. This is important to check before moving to any deeper discussion. If country location of the firm, industry the firm belongs to or size of the firm is affecting the trade credit ratio; their effects will be cleaned before the final model. Our data has relatively large data points. However, considering we have six countries, twenty four industries and three sizes of firms; the number of data points per segment can be an issue if we test everything (country, industry and size effects) at the same time. Instead, we test one by one.

H1:

- **H1a1**: TC ratio differs significantly by the country a firm is located (for firm i located at country j)
  \[ \text{Trade Credit Ratio}_i = \beta_0 + \sum_{j=1}^{6} \beta_j \cdot \text{Country}_{ij} + e_{ij} (\text{country is dummy variable}) \] (1)

- **H1a2**: Bank credit ratio differs significantly by the country a firm is located
  \[ \text{Bank Credit Ratio}_i = \beta_0 + \sum_{j=1}^{6} \beta_j \cdot \text{Country}_{ij} + e_{ij} (\text{country is dummy variable}) \] (2)

- **H1a3**: Internal funding ratio differs significantly by the country a firm is located
  \[ \text{Internal Funding Ratio}_i = \beta_0 + \sum_{j=1}^{6} \beta_j \cdot \text{Country}_{ij} + e_{ij} (\text{country is dummy variable}) \] (3)

- **H1b1**: TC ratio differs significantly by the industry a firm belongs
  \[ \text{Trade Credit Ratio}_i = \beta_0 + \sum_{k=1}^{24} \beta_k \cdot \text{Industry}_{ik} + e_{ik} (\text{industry is dummy variable}) \] (4)

- **H1b2**: Bank credit ratio differs significantly by the industry a firm belongs
  \[ \text{Bank Credit Ratio}_i = \beta_0 + \sum_{k=1}^{24} \beta_k \cdot \text{Industry}_{ik} + e_{ik} (\text{industry is dummy variable}) \] (5)

- **H1b3**: Internal funding ratio differs significantly by the industry a firm belongs
  \[ \text{Internal Funding Ratio}_i = \beta_0 + \sum_{k=1}^{24} \beta_k \cdot \text{Industry}_{ik} + e_{ik} (\text{industry is dummy variable}) \] (6)

- **H1c1**: TC ratio differs significantly by the size of a firm
  \[ \text{Trade Credit Ratio}_i = \beta_0 + \sum_{l=1}^{3} \beta_l \cdot \text{Firm Size}_{il} + e_{il} (\text{firm size is dummy variable}) \] (7)

- **H1c2**: Bank credit ratio differs significantly by the size of a firm
  \[ \text{Bank Credit Ratio}_i = \beta_0 + \sum_{l=1}^{3} \beta_l \cdot \text{Firm Size}_{il} + e_{il} (\text{firm size is dummy variable}) \] (8)

- **H1c3**: Internal funding ratio differs significantly by the size of a firm
  \[ \text{Internal Funding Ratio}_i = \beta_0 + \sum_{l=1}^{3} \beta_l \cdot \text{Firm Size}_{il} + e_{il} (\text{firm size is dummy variable}) \] (9)

The growth of credit lend through domestic banks is important in measuring the pressure firms feel in securing additional credits from banks. Here the term “domestic banks” refers to not only national
banks but also to international banks that have branches in these countries. The national lending ratios for all of these six countries are lower since they are all emerging countries and need outside investment. For example, the lending ratio over GDP is no higher than 80% for any of these countries whereas in the Western Europe, the same ratio can be as high as double of the GDP. From a different perspective, there is a big opportunity for each country to increase lending. For instance, this credit lend over the GDP ratio was doubled to tripled for all of these countries from 2000 to 2005 while their GDP also grew dramatically. Hence, it is not expected to see a drop in the amount of credit lent even during the financial crisis. However, the growth rate of this measure is expected to be different. The methodology is the same as the one in hypothesis two with classical event study.

H3: The growth in the amount of bank lend through domestic banks drops significantly from the pre-crisis period

\[ \text{The growth in the amount of bank lend through domestic banks}_{jt=1} - \text{The growth in the amount of bank lend through domestic banks}_{jt=0} = \beta_0 + \varepsilon_j \]  

(10)  

(\text{where } j = \text{country}, t = 1 \text{ is during after crisis, } t = 0 \text{ pre crisis period})

Effects of the financial crisis on firm level can be observed through drop in sales. Large-scale negative events such as wars, terrorist attacks, and global economic recessions cause customers to either postpone or cancel purchases. In other words, decreased customer confidence leads decreased sales. Occasionally, customer confidence is labeled as a potentially irrational or overreacted collective set of behavior. This behavior is closely related to agency theory. Agency theory emphasizes the importance of trust between transaction partners. When this trust is broken or decreased due to external event such as crisis, there is increased transaction cost and increased likelihood of adverse selection. When the size of the effect of the global crisis is calculated in firm level, the potential country, size, industry effect needs to be cleaned before running the regression.

H2: During the global financial crisis firms' sales significantly drops

\[ \text{Firm Sales}_{it=1} - \text{Firm Sales}_{it=0} = \beta_0 + \varepsilon_i \]  

(11)  

(\text{where } i = \text{firms}, t = 1 \text{ is during after crisis, } t = 0 \text{ pre crisis period})

Next, it is investigated whether or not the change in growth ratio in credit lent through domestic banks has a direct effect on the bank credit ratio among firms. Credit lent through banks includes many
items, including financing business investment, customer private loans, financing governmental debt, and etc. Here the aim is to assess the pressure of this measure on bank credit. Again, it is important to clean the firm’s banking ratio from country, industry and size effects if necessary. The same is true that the change in the credit lend growth ratio should be cleaned from country effects.

H4: The percentage drop in the credit lent through domestic banks decreases the firm bank credit ratio in the survey countries.

\[ Bank \ Credit \ Ratio_i = \beta_0 + \beta_1 \times \text{Percetange drop in the credit lend through domestic banks}_i + e_i \]  (12)

Other potential factors that are influencing the bank credit ratio of firms include change in firm sales and pre-crisis internal funding ratio. When sales increase, firms need additional financing to support their operations. On the other hand, pre-crisis internal funding ratio shows the financial strength of the firm. Firms use less bank credit when they can sustain their operations with internal funding. Here, a standard regression analysis will be conducted.

H5: An increase in sales increases the bank credit ratio.

\[ Bank \ Credit \ Ratio_i = \beta_0 + \beta_1 \times \text{percent increase in sales}_i + e_i \]  (13)

H8: Companies who have higher internal funding ratio before the crisis need less bank funding afterwards.

\[ Bank \ Credit \ Ratio_i = \beta_0 + \beta_1 \times \text{internal funding ratio before the crisis}_i + e_i \]  (14)

In order to further support hypothesis eight (internal funding ratio indicates financial strength of the firm), a secondary hypothesis between pre-crisis internal funding and delayed payments/financial insolvency will be tested. In the survey, there are various measures for financial hardships: delaying tax and supplier payments, being overdue on obligations to any financial institution in the last three months, filing for readjustment of a firm's debt and capital structure after a bankruptcy or receivership order, filing for bankruptcy, and filing for direct state aid. Any of these measures show problems in management. In the survey, there is a measure of the proportion working capital financed from internal funds and retained earnings from a year ago before the crisis. It is interesting and insightful to see if this measure is able to predict any of the unwanted results. All of these negative outcomes are combined into a single measure of "yes", if the company had any of these problems, or "no", when the company did not have any of these aforementioned problems. First, any of the country, firm, and industry effects on internal funding are
cleaned, then regressed against payment problems using binary logistic regression. In similar fashion, change in sales will be also tested against delayed payments/financial insolvency. Sales drop should be significant reason for any delays in payment and financial insolvency. In return, delayed payments should lead higher trade credit.

H10: A higher level of internal funding ratio percentage decreases the possibility of delayed payments (lower trade credit).

$$\text{logit}(P(\text{Delayed Payments}_i)) = \beta_0 + \beta_1 \times \text{internal funding ratio before the crisis}_i + e_i$$ (15)

H7: A decreased sales increases the possibility of delayed payments (higher trade credit).

$$\text{logit}(P(\text{Delayed Payments}_i)) = \beta_0 + \beta_1 \times \text{sales increase}_i + e_i$$ (16)

H11: Having delayed payments increases the trade-credit ratio

$$\text{Trade Credit Ratio}_i = \beta_0 + \beta_1 \times \text{Delayed Payments}_i + e_i \text{ (delayed payments is a binary variable)}$$ (17)

Next, which measures predicts trade-credit ratio will be discussed. It is crucial for firms who offer trade credit to be able to calculate their risks of getting paid full and on time. Sales change and internal funding ratio of the firm are two strong candidates for the job. These two measures preclude the trade-credit ratio during the crisis period. There are definitely other potential measures that determine/predict the later trade credit. However, only these two measures are present in the survey. Hypotheses are:

H6: A negative change on sales increases trade-credit ratio.

$$\text{Trade Credit Ratio}_i = \beta_0 + \beta_1 \times \text{Sales Increase}_i + e_i$$ (18)

H9: Companies who have higher internal funding ratio before the crisis need less trade credit afterwards.

$$\text{Trade Credit Ratio}_i = \beta_0 + \beta_1 \times \text{internal funding ratio before the crisis}_i + e_i$$ (19)

Lastly, there is an analysis of correlation among trade credit, bank credit and trade-credit ratios. All of these are part of working capital. As so, they are likely to have high correlations. But the signs and magnitudes are important to analyze.
4. Results

Hypotheses 1:

The survey includes firm size, industry, and country specific information. It is needed to understand which of them are important in determining the percentage of trade credit, internal funds and bank credit. Here are the results to the standard t test.

<table>
<thead>
<tr>
<th>Country</th>
<th>Industry</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Internal</strong></td>
<td>R-Sq=86.6%</td>
<td>R-Sq=15.3%</td>
</tr>
<tr>
<td></td>
<td>R-Sq(adj)=85.3%</td>
<td>R-Sq(adj)=0.0%</td>
</tr>
<tr>
<td></td>
<td>F-Test= 66.73</td>
<td>F-Test= 0.77</td>
</tr>
<tr>
<td></td>
<td>P=0.000</td>
<td>P=0.690</td>
</tr>
<tr>
<td><strong>Bank Credit</strong></td>
<td>R-Sq=30.2%</td>
<td>R-Sq=30.0%</td>
</tr>
<tr>
<td></td>
<td>R-Sq(adj)=23.4%</td>
<td>R-Sq(adj)=13.5%</td>
</tr>
<tr>
<td></td>
<td>F-Test= 4.46</td>
<td>F-Test= 1.82</td>
</tr>
<tr>
<td></td>
<td>P=0.001</td>
<td>P=0.060</td>
</tr>
<tr>
<td><strong>Trade Credit</strong></td>
<td>R-Sq=89.7%</td>
<td>R-Sq=17.4%</td>
</tr>
<tr>
<td></td>
<td>R-Sq(adj)=88.7%</td>
<td>R-Sq(adj)=0.0%</td>
</tr>
<tr>
<td></td>
<td>F-Test= 89.6</td>
<td>F-Test= 0.89</td>
</tr>
<tr>
<td></td>
<td>P=0.000</td>
<td>P=0.570</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Country</th>
<th>Industry</th>
<th>Size</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Internal</strong></td>
<td>Important</td>
<td>Not Important</td>
</tr>
<tr>
<td><strong>Bank Credit</strong></td>
<td>Less Important</td>
<td>Less Important</td>
</tr>
<tr>
<td><strong>Trade Credit</strong></td>
<td>Important</td>
<td>Not Important</td>
</tr>
</tbody>
</table>

From the Table 5, important conclusions can be drawn. First, country is the most significant factor compared to industry and size in determining the percentage of internal, bank credit and trade credit. Secondly, bank credit is less dependent on country, industry and size compared to internal and trade-credit funding. Bank credit is harder to determine simply using the country, industry, and size factors. Both industry and size has limited ability to determine funding percentages.

H2: The global financial crisis significantly drops the firms' sales during the global financial crisis period.

After country-specific effects are cleaned, on average, the global financial crisis caused a 30% drop in sales among all the firms in the survey.

H3: The growth in the amount of bank lend through domestic banks drops significantly from the pre-crisis period.
The effects of the late 2000s financial crisis on the banking sector credit are significant. The next figure compares the average growth rate for domestic credit provided by banking sector during the periods of 2000-2011, 2000-2007 and 2008-2011. The drop in banking lending growth across all 6 countries is 24.3% (tstat = 4.35) after country differences are taken into consideration. The population difference between pre and during/after crisis periods are significantly different with 68% test power.

![Graph showing average percentage banking lending growth per year for 2000-2011, 2000-2007, and 2008-2011 for different countries.]

H4: The percentage drop in the credit lent through domestic banks decreases the firm bank credit ratio in the survey countries.

Hypothesis 5 was not supported significantly based on data.

H5: An increase in sales increases the bank credit ratio.

Hypothesis 6 was not supported significantly based on data.

H6: A negative change on sales increases trade-credit ratio.

Hypothesis 7 is supported and significant ($F = 87.88, p = 0.000, R-sq = 30.3\%$). Every 1% in sales leads to .04% increase in trade credit.

H7: A decreased sales growth leads higher possibility of delayed payments.

Hypothesis 8 is supported significantly ($z = -3.62, p = .000$) based on a binary regression.

H8: Companies who have higher internal funding ratio before the crisis need less bank funding afterwards.

After cleaning country effects on both bank funding ratio and internal funding ratio before the crisis, there is a significant impact of internal funding ratio on bank credit ratio ($t = -14.13, p = 0.000$).
There is a negative effect on high internal funding ratio before the crisis. Size of the effect is roughly a 0.24% decrease for every 1% increase in internal funding ratio before the crisis. Those companies who managed to have a higher internal funding ratio during the crisis and needs less bank credit afterwards. As an example, if a company uses 10% more internal funding than its peers, the same country before the crisis, the same company would have 2.4% more trade-credit needs compared to its peers. This number is half of the earlier trade-credit ratio. In other words, companies are more likely to seek for trade credit than bank credit by 2 to 1 margin.

H9: Companies who have higher internal funding ratio before the crisis also need less trade credit afterwards.

After cleaning country effects on both trade-credit ratio and internal funding ratio before the crisis, there is a significant impact of internal funding ratio on trade-credit ratio ($t = -20.07, p = 0.000$). There is a negative effect of earlier high internal funding ratio. Size of the effect is roughly 0.48% decrease for every 1% increase in internal funding ratio before the crisis. Those companies who managed to have higher internal funding ratio during the crisis, need less trade credit afterwards. As an example, if a company uses 10% more of internal funding than its peers in the same country before the crisis, the same company will have 4.8% more trade-credit needs compared to its peers.

H10: A higher level of internal funding ratio percentage decreases the possibility of delayed payments (lower trade credit).

The result is significant ($z = -3.63, p = 0.000$) and negative. Those companies who have higher internal funding ratio than their country pairs before the crisis are less likely to have problems in payments and working capital later.

H11: Having delayed payments increases the trade-credit ratio

Having delayed payments results in 5.55% higher trade-credit ratio compared to having none ($t = 3.21, p = 0.001$).

<table>
<thead>
<tr>
<th>Correlation</th>
<th>Internal Bank Credit</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bank Credit</td>
<td>-0.374</td>
</tr>
<tr>
<td>Trade Credit</td>
<td>-0.838 -0.192</td>
</tr>
</tbody>
</table>

Table 6: Correlations among bank credit, trade credit and internal funding ratios
All correlation numbers are highly significant even at 1% level. From this figure, it is clear that internal and trade-credit ratios move much closer with each other than bank credit. Following table 7 and figure 11 show the supported hypotheses. Conclusions are the following:

<table>
<thead>
<tr>
<th>Hypotheses</th>
<th>Supported</th>
</tr>
</thead>
<tbody>
<tr>
<td>H1a1: TC ratio differs significantly by the country a firm is located</td>
<td>Yes</td>
</tr>
<tr>
<td>H1a2: Bank credit ratio differs significantly by the country a firm is located</td>
<td>Yes</td>
</tr>
<tr>
<td>H1a3: Internal funding ratio differs significantly by the country a firm is located</td>
<td>Yes</td>
</tr>
<tr>
<td>H1b1: TC ratio differs significantly by the industry a firm belongs</td>
<td>No</td>
</tr>
<tr>
<td>H1b2: Bank credit ratio differs significantly by the industry a firm belongs</td>
<td>No</td>
</tr>
<tr>
<td>H1b3: Internal funding ratio differs significantly by the industry a firm belongs</td>
<td>No</td>
</tr>
<tr>
<td>H1c1: TC ratio differs significantly by the size of a firm</td>
<td>No</td>
</tr>
<tr>
<td>H1c2: Bank credit ratio differs significantly by the size of a firm</td>
<td>No</td>
</tr>
<tr>
<td>H1c3: Internal funding ratio differs significantly by the size of a firm</td>
<td>No</td>
</tr>
<tr>
<td>H2: The global financial crisis significantly drops the firms' sales during the global financial crisis period.</td>
<td>Yes</td>
</tr>
<tr>
<td>H3: The growth in the amount of bank lend through domestic banks drops significantly from the pre-crisis period.</td>
<td>Yes</td>
</tr>
<tr>
<td>H4: The percentage drop in the credit lent through domestic banks decreases the firm bank credit ratio in the survey countries.</td>
<td>No</td>
</tr>
<tr>
<td>H5: An increase in sales increases the bank credit ratio.</td>
<td>No</td>
</tr>
<tr>
<td>H6: A negative change on sales increases trade-credit ratio.</td>
<td>Yes</td>
</tr>
<tr>
<td>H7: A decreased sales increases the possibility of delayed payments</td>
<td>Yes</td>
</tr>
<tr>
<td>H8: Companies who have higher internal funding ratio before the crisis need less bank funding afterwards.</td>
<td>Yes</td>
</tr>
<tr>
<td>H9: Companies who have higher internal funding ratio before the crisis also need less trade credit afterwards.</td>
<td>Yes</td>
</tr>
<tr>
<td>H10: A higher level of internal funding ratio percentage decreases the possibility of delayed payments</td>
<td>Yes</td>
</tr>
<tr>
<td>H11: Having delayed payments increases the trade-credit ratio</td>
<td>Yes</td>
</tr>
</tbody>
</table>

Table 7: Summary of hypotheses and results

Figure 11: Supported hypotheses in the general model
5. Discussion

The crisis of the late 2000s significantly affected all these countries. However, this effect differs from country to country. For instance, Kazakhstan and Turkey had fewer issues compared to Hungary, Latvia, Romania, and Bulgaria. During this period, bank lending either dropped nominally or grew much slower than before for all these countries. Moreover, for all these countries, bank credit is lower than internal funding, and it is 5%-10% of the working capital requirement. Except for Hungary, the remaining countries, which are from 5% to 20%, do not use TC as a primary source for working with capital, while in Hungary it is up to 70%. However, companies in this region use primarily internal funds. The level of internal funds before the crisis is actually a good sign for later payment delays and business hardships. Companies with a higher level of internal funding are less likely to have delayed payments or insolvency issues. The same ratio also signals TC and bank-funding needs. For each 1% increase in internal funding, there is 0.48% drop in TC and 0.24% drop in bank credit. This 2:1 ratio difference also signals preference or ability of TC compared to bank credit.

Furthermore, companies that increase their sales or have fewer problems in payments, have lower TC needs. Even though the size of the company matters for decreases in sales, size does not play an important role in TC or bank credit decisions. In addition, industry is an important factor in decreased sales. On the contrary, TC and internal funding are not differentiated by an industry or a size of a company, but instead only by the country the firm is located at. Country is the single most important factor for internal, bank credit, and TC funding. Bank credit is more homogeneous across these countries, industries, and size.

6. Conclusions

Managing working capital and trade credit are important for all businesses, regardless of size of business. Companies can be on both sides of the game: those who provide trade credit, and those who seek for it. Using primarily trade credit and bank credits is not possible for all firms in every situation. The study clearly shows that except for Hungary, for all of the countries in the study, namely Bulgaria, Kazakhstan, Latvia, Romania, and Turkey, the internal funding is a far more important source of working capital funding. In the study, lower internal funding ratios are actually signals of increased financial problems and increased needs of trade credit and bank credit. Hence, when a foreign company sells...
products and services to these countries, they should consider the potential internal funding ratios of buyer firms in order avoid future trouble. Trade credits and internal funding ratios differ significantly from one country to another, whereas bank credit ratios are less significantly different. Therefore, foreign firms should consider the specific condition of a country in which they invest or do business, especially in terms of managing trade credit and bank credits. Because the industry is a less important issue compared to the country factor, multinational countries can channel internal funding to the operations in countries with fewer trade-credit and bank-credit options. Similarly, local firms may consider excessive trade-credit and bank credit requests as being financially unstable. As a result, multinational firms should be careful in using these funding methods. For instance, getting bank credits in countries with rather larger financial markets and using those funds in countries similar to these six countries would make their needs for trade credit and bank credit lower.
REFERENCES


UPGRADING MAINTENANCE EXPERIENCE BY EMBEDDING SENSORS INTO REFRIGERATORS

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ABSTRACT

Selecting the optimal maintenance strategy by which producers’ maintenance costs can be reduced while also delivering products of the quality consumers expect can be challenging for manufacturers and service providers. This paper proposes embedding sensors into refrigerators and subsequently using them to monitor the performance of key components during the life cycle of the refrigerator as a predictive maintenance strategy. The sensors monitor the refrigerators and acquire information about their use patterns as a means of acquiring data that can be employed to estimate the operating performance of the refrigerators and their components and, thereby, predict potential failures. Through monitoring the performance of a system in this way, producers can ensure timely actions are taken to maintain refrigerators. To ascertain the economic impact of the sensors, sensor embedded refrigerator (SER) systems are compared with regular refrigerator (RR) systems. The systems were modeled through the use of discrete event simulations. Design of experiments was employed to run experiments with the models. Pairwise t-tests were then performed to determine whether there was a significant difference in the cost of maintenance of the two systems. The results reveal that sensors can improve maintenance operations significantly by reducing the inspection, productivity loss, and overall maintenance costs.  

Keywords: maintenance, predictive maintenance, closed-loop supply chain, warranty, sensor embedded products

1. INTRODUCTION

The forward supply chain has been in use for many years. It focuses on identifying methods by which the performance of the overall supply chain can be improved such that profit is maximized for every participant in the chain while also optimizing customer value. Customer value consists of many elements including perceived quality, purchase price, product sustainability, product accessibility, and lead time. Sustainability is an important customer value that can be delivered by issuing a warranty with products and offering customers a high-quality maintenance service. However, providing warranty for the products and maintaining them during their life cycles can be financially burdensome for the manufacturers due to unpredictability and high maintenance costs. Sensors can potentially reduce costs by tracking the products throughout their life cycles and collecting data on each component [1] so that proactive maintenance activities can be implemented. The information gathered by sensors may consist of the environment a
product is used in and the use pattern, etc. and it can be subsequently used to predict component failures before they occur, thereby allowing producers to take preventative actions in advance of an issue occurring.

Several studies have reported the benefits of using sensors in reverse supply chain systems [2] [3] [4] [5] [6] [7]. The information that is retrieved from the sensors can be used to estimate the remaining lives of the components, which facilitates the inspection and disassembly processes of end-of-life (EOL) products. For example, if the components are determined to be in bad condition for reuse, a product will not be disassembled. Sensors eliminate the inspection process through proactively providing data about the condition of the components and, as such, they deliver substantial cost savings. A series of papers [2] [3] [4] [5] [6] [7] demonstrated the benefits of sensors by embedding them into different kinds of products such as refrigerators, dishwashers, washing machines, dryers, cooktops, ovens, ranges, air conditioners, and computers.

Ondemir and Gupta [8] [9] [10] studied sensor-embedded products. They focused on identifying methods by which products could be disassembled in a cost-effective manner while also ensuring demands for remanufactured products were fulfilled. They built remanufacture-to-order systems models and employed different techniques, such as fuzzy goal programming, Internet of Things, and integer programming, to solve them. In an alternative series of papers [11] [12] [13], sensor-embedded cell phones were studied in depth. Closed-loop supply chain system models for cell phones that included disassembling EOL cell phones, classifying them into several quality bins, and remanufacturing disassembled components based on their qualities were built for both regular and sensor-embedded cell phones before their economic performances were compared. The researchers concluded that the sensor-embedded cell phone systems were superior to their non-sensor counterparts.

In addition to assessing the benefits of using sensors within EOL processing, Dulman and Gupta [14] evaluated their use in maintenance activities. They found that the condition information that was collected on the components was not only useful for EOL processing, but it was also helpful in anticipating the future failures of the products. This improved the overall maintenance experience by decreasing the manufacturer’s maintenance costs while also improving the customer satisfaction rate by preventing catastrophic failures and reducing the downtime of the products.

The purpose of this study was to examine methods by which refrigerators can be maintained in a manner that optimizes benefits for both producers and consumers. Specifically, the research assessed the performance of sensor-embedded refrigerators and the extent to which these sensors delivered tangible benefits in terms of maintenance activities. The economic performance of regular refrigerator systems and sensor-embedded systems were compared through the use of a design of experiments study. The two systems were developed by using discrete event simulation software, Arena 14.7 [15]. The economic performance of the systems was then compared. The results revealed that the sensor-embedded refrigerator system delivered a superior performance to the regular refrigerator system.

2. METHODOLOGY

The maintenance aspect of the systems starts from the beginning of the use phase of the refrigerators and continues until the life cycle is completed. The producer’s goal during the use phase of the refrigerators is to maintain the system such that consumers are satisfied with the
performance of the product. If the refrigerators fail, the required service is provided. Figure 1 represents the overall life cycle of a refrigerator.

Figure 1. Maintenance and Service Cycle

Regular refrigerator (RR) and sensor-embedded refrigerator (SER) systems are introduced in the following two subsections. The design of experiments study is explained in subsection 2.3.

2.1. Regular Refrigerator System

In RR systems, a corrective maintenance strategy is followed. This involves performing the required maintenance upon the failure of one or more components. If a refrigerator fails, the failure is detected via an inspection and a repair service is initiated. If necessary, the refrigerators are transferred to the facility in which maintenance operations are performed. Otherwise, repairs may be performed on site. During the maintenance process, service personnel replace any faulty components with new ones. Thus, the refrigerators are returned to full working condition. If these operations are performed in the facility, the refrigerators are delivered to the customer, and this completes the maintenance cycle for this failure instance. Figure 2 presents an overview of the flow of maintenance of RR systems.

During the period of repair, the manufacturer encounters several costs as a result of the failure, such as inspection, material replacement, logistics, and productivity loss costs. The failed refrigerators require inspection, and this translates to inspection costs. Logistics costs include transportation of the failed refrigerators for maintenance. Material replacement costs occur as a result of the need to replace components. Moreover, productivity losses occur due to the refrigerators being out of use.

Figure 2. Maintenance of RR Systems
2.2. Sensor Embedded Refrigerator System

In SER systems, sensors are embedded into refrigerators during the manufacturing process. SER systems allow the use of a predictive maintenance strategy by which potential issues with RR systems are identified and proactively remedied. Sensors monitor the refrigerators during their use phases and collect data related to their use patterns and performance. This information is subsequently used to determine the condition of the refrigerators and their components and to estimate failures before they occur. Thus, proper maintenance is provided prior to failure, thereby preventing any catastrophic issues from arising. Figure 3 demonstrates the flow of maintenance of SER systems.

In these systems, inspection is not required because the sensors provide the condition information about the refrigerators and components. Most importantly, the productivity loss cost is reduced because the downtime is reduced.

Figure 3. Maintenance of SER Systems

2.3. Design of Experiments Study

To compare the RR and SER systems, this research employed a design of experiments approach. First, the factors that can potentially impact the performance measures of the systems were determined. These factors are provided in Table 1. Each factor has two levels.

Table 1. Maintenance Factors

<table>
<thead>
<tr>
<th>Maintenance Factors</th>
<th>Level 1</th>
<th>Level 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Recognition of Failure and Service Activation</td>
<td>3 days</td>
<td>1 day</td>
</tr>
<tr>
<td>Inspection Time of Failure (min) (Normally Distributed)</td>
<td>(20,1.2)</td>
<td>(15,1.2)</td>
</tr>
<tr>
<td>Labor Cost</td>
<td>$30/hour</td>
<td>$20/hour</td>
</tr>
</tbody>
</table>
As explained in the previous section, recognition of failure and service activation takes time, and this incurs productivity loss costs. Thus, recognition of failure and service activation time was included in factors. In addition, inspection time was also included as a factor. Inspection time is assumed to be normally distributed with the mean and standard deviation values that are shown in the parenthesis. Labor costs are associated with inspection time and are a function of inspection cost. Moreover, productivity loss costs, which are a function of refrigerator value and its expected life span, were also considered as a factor. Additional data is provided in Tables 2 to 5.

**Table 2. Maintenance Data**

<table>
<thead>
<tr>
<th>Maintenance Data</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Failure Arrival Rate (day) (Exponentially Distributed)</td>
<td>0.047</td>
</tr>
<tr>
<td>Expected Lifetime (year)</td>
<td>10</td>
</tr>
<tr>
<td>Transportation Before Service (day)</td>
<td>1</td>
</tr>
<tr>
<td>Delivery After Service (day) (Triangular Distribution)</td>
<td>Min (1), Mean (2), Max (3)</td>
</tr>
<tr>
<td>Transportation Cost ($)</td>
<td>10</td>
</tr>
<tr>
<td>Delivery Cost ($)</td>
<td>60</td>
</tr>
</tbody>
</table>

Refrigerator failures are introduced into the system with exponential interarrival times. The expected lifetime of the refrigerators is ten years. It takes one day to send the failed refrigerators to the maintenance facility if needed. The delivery time taken to return the refrigerators to the customers follows a triangular distribution. The costs associated with transportation and delivery are presented in Table 2.

**Table 3. Subassembly and Component Replacement Times for Maintenance**

<table>
<thead>
<tr>
<th>Subassembly and Component Replacement Times for Maintenance (Normally Distributed) (Mean, Standard Deviation)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Metal Cover (min)</td>
<td>(1,0.1)</td>
</tr>
<tr>
<td>Aluminum Radiator (min)</td>
<td>(1,0.1)</td>
</tr>
<tr>
<td>Motor (min)</td>
<td>(2,0.3)</td>
</tr>
<tr>
<td>Solenoid Valve (min)</td>
<td>(3,0.4)</td>
</tr>
<tr>
<td>Circuit Board (min)</td>
<td>(5,1)</td>
</tr>
</tbody>
</table>

Table 3 provides the replacement times of the components and subassemblies. They are normally distributed.

**Table 4. Subassembly and Component Replacement Costs for Maintenance**

<table>
<thead>
<tr>
<th>Subassembly and Component Replacement Costs for Maintenance</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Metal Cover ($)</td>
<td>40</td>
</tr>
<tr>
<td>Aluminum Radiator ($)</td>
<td>120</td>
</tr>
</tbody>
</table>
Table 4 shows the material replacement costs for subassemblies and components.

Table 5. Subassembly and Component Failure Probabilities

<table>
<thead>
<tr>
<th>Subassembly and Component Failure Probabilities (%)</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Metal Cover Failure</td>
<td>5</td>
</tr>
<tr>
<td>Aluminum Radiator Failure</td>
<td>30</td>
</tr>
<tr>
<td>Motor Failure</td>
<td>25</td>
</tr>
<tr>
<td>Solenoid Valve Failure</td>
<td>10</td>
</tr>
<tr>
<td>Circuit Board Failure</td>
<td>30</td>
</tr>
</tbody>
</table>

Table 5 provides the failure distribution rate of the components. For example, if a refrigerator fails the chance of metal cover failure is 5%.

To run the experiments, the systems were modeled using discrete event simulation using the Arena 14.7 tool [15]. Several performance measures, such as inspection, logistics, material replacement, and productivity loss costs, were collected during the experiments. The function below shows the overall maintenance cost of the systems.

\[
\text{Maintenance Cost} = \text{Inspection Cost} + \text{Logistics Cost} + \text{Material Replacement Cost} + \text{Productivity Loss Cost}
\]

3. RESULTS AND DISCUSSION

To allow sufficient time to complete the refrigerators’ life cycles, the simulations were executed over a 4200-day period, which is approximately 11.5 years. The maintenance costs of the two systems were calculated per refrigerator, and these values are presented in Table 6. The maintenance cost per refrigerator was $161.59 for the SER system and $196.16 for the RR system. To determine whether the difference between these two systems was significant or not, pairwise t-tests were performed. The results revealed that the p-value was less than 0.0001 and, as such, it was concluded that the difference between the two systems was of a high statistical significance. Embedding sensors into the refrigerators can save as much as $34.57 per refrigerator.

Table 6. T-Test Results

<table>
<thead>
<tr>
<th>Measure</th>
<th>Maintenance Cost / Refrigerator</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean Difference (SER-RR) ($)</td>
<td>-34.57</td>
</tr>
<tr>
<td>P-Value</td>
<td>&lt;0.0001</td>
</tr>
<tr>
<td>SER System ($)</td>
<td>161.59</td>
</tr>
<tr>
<td>RR System ($)</td>
<td>196.16</td>
</tr>
</tbody>
</table>
In addition to t-tests, different failure interarrival times were also tested in this study. By keeping all other factors the same and changing the failure interarrival times, the researchers examined different scenarios. The results were plotted and are presented in Figures 4 and 5. Failure interarrival rates were increased, and this resulted in fewer failures. Thus, the maintenance costs of the systems exhibited an exponential downward trend. These values are presented in Figure 4. In addition to the maintenance cost of the systems, the cost difference between the systems also exhibited a similar downward trend, as can be seen in Figure 5.

![Maintenance Cost of The Systems](image)

*Figure 4. Maintenance Cost Plot*

![Maintenance Cost Difference](image)

*Figure 5. Maintenance Cost Difference Between Systems*

4. CONCLUSION

This paper evaluated the use of sensors to improve the maintenance activities of refrigerators. By embedding sensors into the refrigerators, a predictive maintenance strategy was followed. To determine the economic impact of the sensors, two systems, RR and SER, were modeled via discrete event simulation. The models were run by utilizing a design of experiments study. The experiment results showed that sensors can optimize the performance of maintenance.
activities by accurately predicting failures in advance. The use of sensors can reduce maintenance costs by $34.58 per refrigerator. As such, embedding sensors into refrigerators can significantly enhance business profitability.

REFERENCES

Waste Management in Sustainable Food Supply Chain through Reverse Logistics

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Abstract

In this paper, we study the problem of designing a model of a food distribution network that reduces the cost in a nonprofit supply network and increases benefits to stakeholders. We developed a model for the Saudi Food Bank. The goal of the model is to determine the number and location of the distribution centers in order to cover the determined areas with least cost and best utilization of the food bank resources. A Mixed Integer Linear Programming (MILP) model is formulated. By solving the model for different budget constraints, we identify a level of decentralization of the food distribution centers by which the responsiveness of the system is increased. Finally, we provide suggestions to increase the efficiency of the food distribution process and discuss areas of future research studies.

Keywords: Reverse Logistics, Food Supply Chain, Network Design, Food Waste

INTRODUCTION

As an expected consequence of increasing consumption of different types of products and as a result of the high rate of purchasing process of new products, particularly in the electronics products sector, a need for better treatment of used products arises in the supply chain management planning. This need becomes essential since the environmental awareness increases and countries'
environmental regulations become stricter [1]. As a result, the term "Reverse logistics" appears in the literature as a part of the supply chain management process. Reverse logistics can be defined as the activities related to product recovery and the process of deciding the best disposal option of different products [2].

Much of the current research in operations management and economics has focused on cost effectiveness of recycling, on political and economic strategies to encourage recycling by influencing both supply and demand, and on methods to create effective, efficient, and optimal logistical paths for product return [3]. The social and ethical dimensions of sustainability, however, particularly as they apply to Reverse Logistics (RL), remain inchoate topics [4]. Nonprofit supply chain is the term that is usually applied to such topics.

In this paper we will investigate the problem of designing food waste distribution network in the context of nonprofit organizations. Our aim is to determine the number and location of the distribution centers in order to cover the determined areas with least cost and best utilization of the food bank resources. A mixed integer linear programming (MILP) model is formulated for returned excess food. The delivered model is utilized to analyze the existing network of the Saudi Food Bank organization. This organization aims to reduce food waste by adopting this initiative from the worldwide idea of food banks.

The remainder of this paper is organized as follows: the system is described in section II and model assumptions are presented. Section III presents the numerical analysis and the computational results. Finally, we conclude in Section IV and present future research areas.

SYSTEM DESCRIPTION

A. Food Bank Process Description

The food bank processes consist of three main stages, namely, the planning stage, the packaging stage and the distribution stage. In the planning stage a weekly schedule is constructed of all events held in hotels, restaurants and companies collaborating with the food bank. Then, scheduled events are allocated to the teams and assign a supervisor to each team.

In the packaging stage, the supervisor and team begin to test the surplus food in terms of color, smell and taste. Nonconforming food will be appropriately disposed of. Then, the temperature of the conforming food is measured to establish that it satisfies certain health criteria. Then, the conforming food is placed in special boxes. These boxes are then packaged and information is written on each box that shows the date and time of collection. The packaged boxes are collected in baskets and placed in cars equipped for food storage.

In the distribution stage, the food baskets are delivered to two central charities, one in Dammam City and one in Khobar City. From there they are distributed immediately to beneficiaries.

B. Food Waste Collection and Redistribution System
In the commercial reverse logistics, reverse production systems (RPSs) include collection, sorting, remanufacturing, and refurbished processes networked by reverse logistics operations to recover discarded products [5]. On the other hand, in the nonprofit reverse logistics environment, collection and redistribution systems (CRSs) include collection, sorting, recycling, and redistribution processes networked by reverse logistics operations to recover different returned products for the benefit of society. CRS model can be represented by a multi-tier network, where returned products, such as leftovers, end-of-life electronic devices or remnants of pharmaceuticals, flow between these tiers from an upstream boundary tier to a downstream one through intermediate tiers. Centers in the upstream tier that could be seen as nonprofit organizations collect returned products from supply sources, such as residential households, businesses, schools, hotels, pharmacies or the government. The quantity of the collected items can be different from one source to another depending on the collection response time, the size of the source and the willingness to donate. The Intermediate tiers may contain several levels of centers which receive these returned products and perform value-added processes such as sorting, disassembling or recycling operations. Centers in the downstream tier collect returned products from intermediate centers and conduct refurbishment processes before the distribution to individuals who are scattered in different locations.

The scope of this study is focused on the design of a food waste collection and redistribution system that connects the targeted areas and their surroundings. The food bank will be collaborating with many hotels and restaurants which will represent supply sources of food waste. Supply sources are scattered in different places in the expanded areas. The food bank is required to collect food waste in all events held in those supply sources at any time in order to distribute it to individuals who usually accept all quantities of food offered.

The food bank task is to collect and distribute this food to beneficiaries at the right time, at the lowest cost and highest quality. Arriving at the supply source a long time before the end of the event will cause resources to lie idle. At the same time, arriving at the supply source a long time after the event will cause problems for the supply source and may result in food spoilage. Further, we need to determine the appropriate amount of resources that match the quantity of food waste and reducing the cost of transportation between different tiers.

In order to ensure the achievement of the goal of the food bank in terms of increasing the amount of food collected and redistributed to the beneficiaries at the lowest cost and highest quality, we will consider a scenario that determines the degree of decentralization of the collection and redistribution processes and balances between collecting the largest amount of food waste and the cost of collection, storage and redistribution to individuals. In this scenario, collection and redistribution centers should be located in areas that combine proximity to supply sources and areas with high demand density. When events are held in supply sources, the necessary resources must be provided to them at the right time. After that, food waste is collected and transferred to the collection and redistribution centers for storage before transporting to the beneficiaries through the local charity organizations. Fig. 1 shows nonprofit collection and redistribution network structure, which consists of M1 scattered supply sources, candidate collection and redistribution centers where the upstream, intermediate and downstream tiers are combined in one tier and M3 locations in the demand tier. The dashed arrows in the figure indicate that we need to determine the optimal solution among these potential assignments.
The following assumptions are considered in the model formulation:
1. The collection of the food can be achieved at different coverage levels, where each coverage level, $l$, is characterized by an upper and lower response time limit $UR_l$, and $LR_l$, respectively.
2. The coverage efficiency, $\alpha_l$, decreases as coverage level increases, and is represented by a decreasing step function. That is, for coverage levels $1 \leq 2 \leq \ldots \leq 1 \leq \ldots \leq L$, the associated efficiencies are $\alpha_1 > \alpha_2 > \ldots > \alpha_l > \ldots > \alpha_L \geq 0$.
3. $N_s(l)$ represents the set of collection and redistribution center (CRC) candidates that can provide coverage level $l$ for food provided by supply source $i$.
4. We assume food waste characteristics (criticality, response time limits) are identical for different supply sources.
5. Collection of food waste can only be achieved from CRCs that can cover the corresponding supply source location.
6. The cost of establishing CRCs is constrained by a setup budget.
7. The transportation costs associated with collecting and delivering food waste supplies from supply sources to CRCs and from CRCs to demand locations for any event scenario are assumed to be limited by a redistribution budget.
8. Multiple supplies will not occur simultaneously.
9. Capacity restrictions on each CRC in the network are imposed.

**NOMENCLATURE**

The following nomenclature is used in the formulation of the facility location model for CRCs:

**Sets**

$M$  set of demand locations; $k \in M$
N set of candidate CRCs; \( j \in N \)

S set of supply sources; \( i \in S \)

**Parameters**

\( B_0 \) budget allocated for establishing CRCs (SR)

\( B_1 \) budget allocated for redistribution process (SR)

\( \text{Cap}_j \) capacity of CRC \( j \) (volume)

\( c_{jk} \) unit cost of shipping food waste from CRC \( j \) to demand location \( k \) (SR/unit)

\( D_k \) expected demand of food waste in demand location \( k \) (units)

\( F_j \) fixed cost of establishing CRC \( j \) (SR)

\( g_{ij} \) unit cost of transporting food waste of supply source \( i \) to CRC \( j \) (SR/unit)

\( l \) coverage level for food waste

\( N_i(l) \) candidate CRC locations that can provide \( l \) coverage level for food waste for supply source \( i \); \( N_i(l) = \{j|LR_l < t_{ij} \leq UR_l\} \)

\( p_i \) probability of occurrence of supply source \( i \)

\( t_{ij} \) time to transport food waste from supply source \( i \) to CRC \( j \) (minutes)

\( U_i \) expected amount of food waste in supply source \( i \) (units)

\( LR_l \) lower response time limit defines coverage level \( l \)

\( UR_l \) upper response time limit defines coverage level \( l \)

\( \gamma \) unit volume of food waste

\( \alpha_i \) coverage level weight \( \alpha_1 = 1 > \alpha_2 > \cdots > \alpha_l > \cdots > \alpha_L \geq 0 \)

**Decision variables**

\( d_{jk} \) proportion of food waste demand \( k \) satisfied by CRC \( j \)

\( f_{ij} \) proportion of food waste acquired by CRC \( j \) in supply source \( i \)

\( X_j = \begin{cases} 1, & \text{if CRC } j \text{ is located} \\ 0, & \text{otherwise} \end{cases} \)
PROBLEM FORMULATION

The formulation for the problem is as follows:

\[
    \text{max} \sum_i \sum_{j \in N_i(l)} \sum_l p_i \alpha_l U_i f_{ij} \tag{1}
\]

Subject to

\[
    \sum_{i \in S} \gamma U_i f_{ij} \leq \text{Cap}_j X_j \quad \forall j \in N \tag{2}
\]

\[
    \sum_{j \in N} (F_j X_j) \leq B_0 \tag{3}
\]

\[
    \sum_{j \in N} \left( \sum_{k \in M} D_k d_{jk} c_{jk} + \sum_{i \in S} U_i f_{ij} g_{ij} \right) \leq B_1 \tag{4}
\]

\[
    \sum_{k \in M} D_k d_{jk} - \sum_{i \in S} U_i f_{ij} = 0 \quad \forall j \in N \tag{5}
\]

\[
    \sum_{j \in N} f_{ij} \leq 1 \quad \forall i \in S \tag{6}
\]

\[
    \sum_{j \in N} d_{jk} \leq 1 \quad \forall k \in M \tag{7}
\]

\[
    f_{ij}, d_{jk} \geq 0 \quad \forall i \in S, \forall k \in M, \forall j \in N \tag{8}
\]

\[
    X_j \in \{0,1\} \quad \forall j \in N \tag{9}
\]

The objective function (1) maximizes the total expected supply of food waste covered by the established CRCs. Constraint set (2) guarantees that the supply is held only at established CRCs, and the amount of supply kept at any of these centers does not exceed its capacity. Constraint (3) requires that the expenditures related to establishing a CRC do not exceed the determined budget, and constraint set (4) guarantees that the transportation costs incurred between supply sources, CRCs and demand locations are less than the expected redistribution process.
budget. Constraint set (5) guarantees that the amount of supply collected from supply sources is redistributed totally to demand locations. Constraint set (6) ensures the amount of collected food waste of a supply source does not exceed the actual food waste. Constraint set (7) ensures the amount of food waste sent to satisfy the demand does not exceed the actual demand. Finally, constraint set (8) is the non-negativity constraint on the proportion of food waste collected and proportion of demand satisfied and constraint set (9) defines the binary location variable.

**NUMERICAL ANALYSIS**

In this section, we introduce the implementation of the proposed collection and redistribution network design model and present computational results.

**A. The Data Set**

The parameters that are required to analyze the model are developed by analyzing the data obtained from the food bank database that contains data collected between 2012 and 2013 for the cities of Dammam and Alhasa. From this database, we identified the locations of the source suppliers, the number of visits for each supplier and the amount of supply at each visit. The total number of supply sources which have a contract with the food bank is 50, 20 of which are hotels, 19 wedding halls, 8 restaurants, 2 universities and one company. We grouped supply sources based on their supply level. For our computational experiments, we estimated the probability of occurrence associated with each supply source based on past data for number of visits. Supply source occurrence likelihood was assumed to be equal to the fraction of visits for the same supply level. We assumed two coverage levels for food waste. The lower and upper response time limits are set to one and two hours, respectively. The first and second coverage benefit levels are set to 1 and 0.7, respectively. For the location of the demand points, we consider it to be the location of charities through which the food bank is delivering excess food to beneficiaries. We are not

<table>
<thead>
<tr>
<th>Candidate center</th>
<th>Capacity</th>
<th>Fixed cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Type 1</td>
<td>1800 meals</td>
<td>400,000 $</td>
</tr>
<tr>
<td>Type 2</td>
<td>5400 meals</td>
<td>1,800,000 $</td>
</tr>
</tbody>
</table>

Unit cost of collecting a meal: 4.585 ($/mile) × distance between points (mile)

Delivery time between candidate center and supply source or demand: Distance between points (mile) / 60 (mile / hrs.)

Unit cost of distributing a meal to demand points: 3.585 ($/mile) × distance between points (mile)
considering the process of distributing food waste from charities to beneficiaries. As a result we have 9 demand locations. According to the collected statistics, the demand always exceeds the supply. For the location of candidate centers, we constructed grid cells with dimensions of one kilometer between each one inside the city and two kilometers outside the city and located a candidate center at the corner of each grid cell. The resulting candidate center locations number 600.

The unit volume of the meal box is 0.0015 m³. There are two types of centers. The cost of collecting and distributing a meal is the sum of transportation vehicle expenses and labor cost as a rate of traveled kilometers. The parameters required by the model are summarized in Table 1.

B. Computational Results

In this section, we present and discuss the results obtained by solving the model for the above parameters using LINGO 13.0. We ran the model for the current existing operations by the food bank at budget constraints specified by the management. The results are provided in Table 2. By solving the model at different combinations of budgets, we obtain a better alternative solution that reduces the required budget by 13.3 %. The details of this solution are shown in Table 2. Fig. 2 shows the current and alternative solutions and connections between the opened CRCs, supply sources and demand points for the city of Dammam. Fig. 3 shows the solutions for Al-Ahase. The connecting lines of the current CRC is not shown as it is only one CRC.

Fig. 2. Current and alternative model for Dammam
The impact of food supply chain on social, economic, environmental and other aspects is very apparent. Improvements in this field will lead to social consolidation and solve many social problems such as food access equality. At the same time, the advances in this area of study will motivate donators to support nonprofit organizations and increase funds. However, it is not an easy

TABLE 2
Results of current and alternative models

<table>
<thead>
<tr>
<th></th>
<th>Setup budget (B0) ($ million)</th>
<th>Transportation budget (B1) ($ million)</th>
<th>Number of CRC to open</th>
<th>Excess food acquired (%)</th>
<th>Average Response time (hrs.)</th>
<th>Suppliers Served at 1st Coverage Level (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current model</td>
<td>2.2</td>
<td>0.8</td>
<td>2</td>
<td>96</td>
<td>0.15</td>
<td>90</td>
</tr>
<tr>
<td>Alternative model</td>
<td>2.4</td>
<td>0.2</td>
<td>6</td>
<td>100</td>
<td>0.09</td>
<td>100</td>
</tr>
</tbody>
</table>

Fig. 3. Current and alternative model for Al-Ahsa
task to overcome the challenges that face food supply chain which needs to achieve "getting the right food to the right people at the right time". The cornerstone of the resolution of these challenges is to model supply network design that leads to an efficient and effective collection and redistribution of food waste to beneficiaries.

In this paper, we discussed the supply network design of nonprofit reverse logistics and implemented the derived model on collection and redistribution of food waste system. The location of collection and redistribution centers was studied to identify the degree of decentralization which leads to an increase in the speed of response and reduces the wastage of food. Ideas to improve the efficiency of the food bank operations include expanding supply sources coverage to include groceries and supermarkets. This will increase the supply and satisfy more demand with unsold products or those close to expiration date. In addition, the derived model could be extended by including other commodities besides food such as used clothes, electronic devices and remnants of pharmaceuticals that will result in a multi-commodity collection and redistribution system. Also, the derived model could be improved by considering the uncertainty of supply that will lead to develop a stochastic model that considers the randomness of the system parameters. In addition, the model could be studied after releasing the assumption of one scenario at a time and considering different scenarios simultaneously. Also, a simulation study could be conducted to improve the efficiency of the operation of the collection and redistribution system.


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Comparing Environmental Beliefs, Norms and Barriers between Chinese Residents and College Students with the Influences on Solar Photovoltaic Rooftop Adoption Decision

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ABSTRACT

With the rapid economic development and surging demand in energy, China has also observed severe environmental deteriorate, which makes adopting clean energy especially solar photovoltaic (PV) rooftop system critical. However, even with the largest production capacity, China’s solar PV adoption at the distributed level is comparative low. This research aimed at comparing environmental beliefs, norms and barriers between Chinese residents and college students and how these environmental factors influence solar PV adoption decision. Survey questions about seven major environmental attitude factors were adopted [1]. After collecting data from 452 college students and 63 residents in China, this paper showed the interesting findings and the implications for solar PV industry, especially for its marketing strategies.

Key Word: Solar Photovoltaic, Environmental, Empirical Study

INTRODUCTION

Coinciding with an era of rapid economic development, there has been an increasing demand in energy, especially electricity in China. The massive use of coal and natural gas as the major fuel resources to generate electricity, although met the strong demand for energy in the short run, created a series of environmental issues in the long run. As a result, large cities in China have begun facing bigger issues including pollution emissions, which have led to serious
environmental consequences, namely damage to public health [2]. After experiencing and observing day after day of smog, and intensive discussions of climate change and particulate matter (PM 2.5), Chinese people have started to reemphasize the importance of environmental protection. In fact, with European and American focus on advocating sustainability, terminology such as “sustainability”, “low carbon” and “clean energy” have not only become frequently used terms and expressions, but have also led to a sustainable lifestyle, which has started to grow in popularity across China, particularly among Generations Y and Z [3].

With the severe environmental deterioration, different from the for the traditional sources from power generation, renewable energy, such as solar and wind power, emits less pollutants and starts to get popular. Solar power generates electricity through semiconductors and its application can be categorized into two types: centralized system or distributed system. Centralized solar applications are usually large-scale systems run by utility companies, while decentralized applications are photovoltaic (PV) systems installed on the rooftops of residential buildings; business buildings, such as warehouses and shopping malls; and in other public areas, such as municipalities, schools and airports.

Starting as the major exporter, China seized the opportunity of exporting to European countries such as Germany who had initiated high-level feed-in tariffs and PV subsidy policies in 2004. Immediately China had leapfrogged to being the largest producer of PV systems. With more than 300 manufacturers directly involved in the PV system production, and approximately 2,000 companies providing relevant products. More than 70GW PV solar cells and 18.66 GW production capacity of PV modules created a wave of overproduction in this country.

Especially, in 2012, the new 50%-150% tax on the Chinese exported PV panel after the anti-dumping and anti-subsidy investigations from European Commission and the U.S. led to the consequent shrinking international market [4]. China has to rely on its own domestic market. The growth in China’s installed PV capacity in just a few years has been truly astounding, the China reached 19.4 GW in the installed capacity by the end of 2013. More, the National Energy administration estimates that yet another 14GW, conservatively speaking, will be installed in 2014 [5]. The survival and growth of this industry cannot rely solely on government policy subsidies.

The unbalanced distribution of installed capacity in China with large-scale PV power plants are majorly located in the northwestern areas of China due to the local sufficient solar resources, such as long hours of sunshine and large spare landscape. Interestingly, there only has small distributed systems installed in the east areas of China. This distribution is also opposite to the unbalanced economy development in China. In eastern are of China, strong economic development leads to high demand for electricity while western part has limited development without strong demand for electricity. The transmission of energy from the western potentially generating lands to the eastern area becomes the challenge due to significant power loss in the process. With governmental policy, such as the Golden Sun Program, the Chinese government
leaned towards to encourage self-generation and self-consumption of electricity in the eastern area. Therefore, among the target plan of 14 GW in 2014, 8 GW was planned for distributed PV application. However, according to most Chinese experts’ predictions, it will be hard to promote the PV system to residents in the eastern provinces [7,8].

Environmental factors could be some major reasons leading to the lower PV rooftop system adoption. The environmental factors including environmental beliefs, norms and barriers. developed the value-belief-norm theory and they suggested that those holding strong pro-environmental beliefs were generally observed to be highly possible in engaging into pro-environmental actions such as consumer behaviors. Particularly, here focus on peoples’ believe on environmental limit and environmental adoption; Environmental norms is generally believed to be positively related pro-environmental consumer behavior. Environmental norms include price norms factor and action norms factor [1]. Environmental barriers include all the barriers which leads to the difficulties in the process of undertaking pro-environmental consumer behavior; Generally, believe that professional assistance factor, a cost factor and a regulation factor are the major obstacles.

This paper will study 1) whether college students as millennium and regular residents hold the same general environmental beliefs and environmental norms 2) whether they encounter the same environmental barriers; and eventually whether this similarity or difference leads to the same solar PV adoption behavior. This paper sheds light on the environmental influences involved in adopting the solar power system at a distributed level. Such considerations may allow for more strategic interactions with households and homeowners in discussions of solar PV systems installation.

**LITERATURE REVIEW**

To get an overview of the history, status quo and projection of the PV industry in China, interested readers might want to refer to [10] and [11] for detailed information. [11] reviewed the history of China’s solar PV industry and summarized the current status of China’s PV development. Correspondingly, the suggestions here advocate expansion in the domestic market and international markets, establishment of a market access mechanism, an integrated innovative financial system, and a grid-connected power generation system.

The existing literatures relevant to the impact of social factors on solar PV adoption can be categorized into the following three major research streams: 1) policy analysis [12 and 13], 2) economic analysis, and 3) social and cultural impact. In the social strand of solar power research, [14] used a multivariate technique to analyze the factors affecting solar photovoltaic (PV) adoption. [15] explained that technical knowledge, motivation, experiences and familiarity are four critical influences of interest in PV. Under the framework of diffusion of innovation, [16] compared a group of ‘early adopters’ and ‘early majority’ regarding the attitudes towards
domestic solar power systems. For the building-integrated solar energy adoption, [17] argued that policy-oriented market, subsidies, and social interaction/acceptance are the three factors influencing the solar industry’s development. [18] applied a logistic regression model to test the relationship between residential solar thermal adoption at the county level and three indices: socioeconomic index, environmental concern index and environmental index. The paper concluded that counties with higher education levels, less unemployment, and higher levels of disposable or investment income indicated higher interest in adopting solar thermal technology. More recently, [3] investigated a framework between value, lifestyle, personality and environmental behavior intention related to solar power system adoption. He concluded that environmental value has a significant positive effect on ecological lifestyle and solar PV system installation intention.

METHOD

In summer 2016, two surveys were administered in China to regular residents on street and college students on campus from the two major cities in China: Beijing and Shanghai. As to the resident data, Beijing and Shanghai have the most attractions that attract lots of visitors from different cities in China. Since we majorly collected data from the major attractions or at the train station where most respondents are not local people. Similarly, the data we collected on campus at our partner schools, where have also college students representing different parts of China because they all came from their hometowns to Beijing and Shanghai to study.

After a brief explanation of the purpose of the research, the questionnaire was filled. A total of 452 questionnaires were distributed and completed from college students; and resident respondents are 63. Since some data are collected from college students and some are from the residents, we compared the results to show whether there are any significant differences.

The questionnaire included sections relating to the status or the plan of adopting solar PV system, their environmental attitude and demographic information. The survey for college students are using the original questions in English since most of the college students have more than 10-year-study in English and have a fair understanding in English. While for the residents, since they have diversity background in learning, especially training in English, we translated the survey in Chinese.

RESULTS

Demographic characteristics of respondents

The following Table 2 indicates the demographic characteristics of the respondents
Table 2: The demographic of college student respondents

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Range</th>
<th>Percentage from College Students (N=452) %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>Under 20</td>
<td>40.1</td>
</tr>
<tr>
<td></td>
<td>20-30</td>
<td>59.4</td>
</tr>
<tr>
<td></td>
<td>31-40</td>
<td>0.4</td>
</tr>
<tr>
<td>Gender</td>
<td>Male</td>
<td>47.9</td>
</tr>
<tr>
<td></td>
<td>Female</td>
<td>52.1</td>
</tr>
<tr>
<td>Main Occupation</td>
<td>Have no work</td>
<td>92.9</td>
</tr>
<tr>
<td></td>
<td>Have part-time jobs</td>
<td>7.1</td>
</tr>
<tr>
<td>Major</td>
<td>Science</td>
<td>4.21</td>
</tr>
<tr>
<td></td>
<td>Engineering</td>
<td>56.76</td>
</tr>
<tr>
<td></td>
<td>Humanity</td>
<td>9.98</td>
</tr>
<tr>
<td></td>
<td>Business</td>
<td>16.85</td>
</tr>
<tr>
<td></td>
<td>Other</td>
<td>12.2</td>
</tr>
<tr>
<td>Geographic</td>
<td>North China</td>
<td>28.9</td>
</tr>
<tr>
<td></td>
<td>Northeast China</td>
<td>6.3</td>
</tr>
<tr>
<td></td>
<td>East China</td>
<td>31.1</td>
</tr>
<tr>
<td></td>
<td>Southwest China</td>
<td>6.3</td>
</tr>
<tr>
<td></td>
<td>Northwest China</td>
<td>6.5</td>
</tr>
<tr>
<td></td>
<td>South Central China</td>
<td>21.0</td>
</tr>
<tr>
<td></td>
<td>The Other</td>
<td>0</td>
</tr>
</tbody>
</table>

The demographic of college students shows that most respondents are traditional students (under 30) majorly without part-time job. The gender distribution is almost equally among the responses. Students are from different geographic parts of China, but the largest three groups are from East, North and South Central China.

Table 3: The demographic of residents Respondents

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>Range</th>
<th>Percentage from Residents (N=63) %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>Under 20</td>
<td>3.5</td>
</tr>
<tr>
<td></td>
<td>20-30</td>
<td>63.2</td>
</tr>
<tr>
<td></td>
<td>31-40</td>
<td>15.8</td>
</tr>
<tr>
<td></td>
<td>41-50</td>
<td>8.8</td>
</tr>
<tr>
<td></td>
<td>51-60</td>
<td>3.5</td>
</tr>
<tr>
<td>Gender</td>
<td>Male</td>
<td>54.4</td>
</tr>
<tr>
<td>--------------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>Female</td>
<td>45.6</td>
<td></td>
</tr>
<tr>
<td>Highest education</td>
<td>Primary School</td>
<td>3.4</td>
</tr>
<tr>
<td></td>
<td>High School</td>
<td>25.4</td>
</tr>
<tr>
<td></td>
<td>Some College</td>
<td>27.1</td>
</tr>
<tr>
<td></td>
<td>Bachelor Degree</td>
<td>32.2</td>
</tr>
<tr>
<td></td>
<td>Graduate Degree (Master and Above)</td>
<td>11.9</td>
</tr>
<tr>
<td>Main Occupation</td>
<td>Have no work</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>Unskilled or semi-skilled manual worker</td>
<td>18.3</td>
</tr>
<tr>
<td></td>
<td>Professional</td>
<td>11.7</td>
</tr>
<tr>
<td></td>
<td>Management</td>
<td>30.0</td>
</tr>
<tr>
<td></td>
<td>Others</td>
<td>35.0</td>
</tr>
<tr>
<td>Income Range</td>
<td>0-60,000RMB</td>
<td>44.4</td>
</tr>
<tr>
<td></td>
<td>60,000-200,000RMB</td>
<td>38.9</td>
</tr>
<tr>
<td></td>
<td>200,000RMB-400,000RMB</td>
<td>9.3</td>
</tr>
<tr>
<td></td>
<td>Above 400,000RMB</td>
<td>7.4</td>
</tr>
<tr>
<td>Living arrangement</td>
<td>Own a detached house</td>
<td>8.5</td>
</tr>
<tr>
<td></td>
<td>Own an apartment/condo</td>
<td>23.7</td>
</tr>
<tr>
<td></td>
<td>Renting</td>
<td>18.6</td>
</tr>
<tr>
<td></td>
<td>Living with family</td>
<td>49.2</td>
</tr>
<tr>
<td>Geographic</td>
<td>North China</td>
<td>25</td>
</tr>
<tr>
<td></td>
<td>Northeast China</td>
<td>6.7</td>
</tr>
<tr>
<td></td>
<td>East China</td>
<td>38.3</td>
</tr>
<tr>
<td></td>
<td>Southwest China</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Northwest China</td>
<td>5.0</td>
</tr>
<tr>
<td></td>
<td>South Central China</td>
<td>23.3</td>
</tr>
<tr>
<td></td>
<td>The Other</td>
<td>1.67</td>
</tr>
</tbody>
</table>

The demographic of residents in the table 3 shows that most respondents are traditional students (under 30). The gender distribution is still quite equal among the responses. Most of respondents have jobs in Management and other areas and the annual salary lower than 30,000$(200,000Yuan). Among which, most of them have salary even lower than 10000$ (60,000Yuan). Residents are from different parts of China, but the largest three groups are from East, South Central China. Most of them live with family.

**Environmental Attitude**

(1) Environmental Limits Factor:
Residents When humans interfere with nature it often has disastrous consequences

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Undecided</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Installation</td>
<td>No</td>
<td>14.27%</td>
<td>10.68%</td>
<td>8.93%</td>
<td>25.05%</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>59.76%</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>13.10%</td>
<td>9.80%</td>
<td>8.20%</td>
<td>27.90%</td>
</tr>
</tbody>
</table>

Data indicated that residents who installed solar PV almost fully agreed on this statement and environmental limits count for 100% while data indicated that residents who haven't installed solar PV majorly agree on this statement and environmental limits are 66.12%.

College Students When humans interfere with nature it often has disastrous consequences

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Undecided</th>
<th>Agree</th>
<th>Strongly Agree</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Installation</td>
<td>No</td>
<td>5.07%</td>
<td>13.37%</td>
<td>26.86%</td>
<td>35.52%</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>4.69%</td>
<td>10.42%</td>
<td>28.13%</td>
<td>37.50%</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>5.00%</td>
<td>12.90%</td>
<td>27.10%</td>
<td>35.90%</td>
</tr>
</tbody>
</table>

Data indicated that college students who installed solar PV majorly agreed on this statement and environmental limits count for 56.25% while data indicated that college students who installed solar PV majorly agreed on this statement and environmental limits 54.46%.

Comparing the residential data with college students’ data, residents have much clearer understanding of environmental limits. Those residents who installed solar PV even have even stronger believe on this factor.

(2) Environmental Adoption Factor

In terms of environmental adoption factor, we asked

<table>
<thead>
<tr>
<th></th>
<th>Plants and animals exist primarily to be used by humans</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Strongly Disagree</td>
<td>Disagree</td>
</tr>
<tr>
<td>Current Installation</td>
<td>No</td>
<td>27.26%</td>
</tr>
</tbody>
</table>

7
Data indicated that residents who installed solar PV partially agreed on this statement and environmental adoption factor are 40.96%; Data indicated that residents who haven't installed solar PV barely agree on this statement and environmental adoption factor are 23.56%; While college students shows:

<table>
<thead>
<tr>
<th>College Students</th>
<th>Plants and animals exist primarily to be used by humans</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Strongly Disagree</td>
<td>Disagree</td>
</tr>
<tr>
<td>Current Installation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>No</td>
<td>32.43%</td>
<td>35.39%</td>
</tr>
<tr>
<td>Yes</td>
<td>31.75%</td>
<td>37.57%</td>
</tr>
<tr>
<td>Total</td>
<td>32.30%</td>
<td>35.90%</td>
</tr>
</tbody>
</table>

Data indicated that college students who installed solar PV even barely agreed on this statement and environmental adoption factors are 15.34%; Data indicated that college students who haven't installed solar PV barely agree on this statement and environmental adoption factors are 21.21%.

In terms of environmental adoption factors, both residents and college students didn’t show strong intention to agree.

**Price Norms**

According to the empirical data, we found:

<table>
<thead>
<tr>
<th>Residents</th>
<th>I would be prepared to pay higher prices overall in order to protect the environment</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Installation</td>
<td>Strongly Disagree</td>
<td>Disagree</td>
</tr>
<tr>
<td>No</td>
<td>1.85%</td>
<td>3.60%</td>
</tr>
<tr>
<td>Yes</td>
<td>0.00%</td>
<td>0.00%</td>
</tr>
<tr>
<td>Total</td>
<td>1.70%</td>
<td>3.30%</td>
</tr>
</tbody>
</table>

Data indicated that residents who installed solar PV majorly agreed on this statement and price norm counts for 60.24%; Data indicated that residents who haven't installed solar PV majorly agreed on this statement and price norm are 61.72%;
College Students  
I would be prepared to pay higher prices overall in order to protect the environment  

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Undecided</th>
<th>Agree</th>
<th>Strongly Agree</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Current Installation No</td>
<td>2.21%</td>
<td>10.09%</td>
<td>30.38%</td>
<td>47.11%</td>
<td>10.09%</td>
<td>100.00%</td>
</tr>
<tr>
<td>Yes</td>
<td>1.07%</td>
<td>6.95%</td>
<td>22.46%</td>
<td>57.22%</td>
<td>11.76%</td>
<td>100.00%</td>
</tr>
<tr>
<td>Total</td>
<td>2.00%</td>
<td>9.60%</td>
<td>29.00%</td>
<td>49.00%</td>
<td>10.50%</td>
<td>100.00%</td>
</tr>
</tbody>
</table>

Data indicated that college students who installed solar PV majorly agreed on this statement and price norm are 68.98%; Data indicated that college students who haven't installed solar PV majorly agree on this statement and price norm are 57.20%.

**Action Norms Factor**

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Undecided</th>
<th>Agree</th>
<th>Strongly Agree</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Residents No</td>
<td>7.68%</td>
<td>0.00%</td>
<td>5.81%</td>
<td>28.84%</td>
<td>57.68%</td>
<td>100.00%</td>
</tr>
<tr>
<td>Yes</td>
<td>0.00%</td>
<td>0.00%</td>
<td>0.00%</td>
<td>60.23%</td>
<td>39.77%</td>
<td>100.00%</td>
</tr>
<tr>
<td>Total</td>
<td>7.00%</td>
<td>0.00%</td>
<td>5.30%</td>
<td>31.60%</td>
<td>56.10%</td>
<td>100.00%</td>
</tr>
</tbody>
</table>

Data indicated that residents who installed solar PV almost fully agreed on this statement and action factor norms are 100%; and data indicated that residents who haven't installed solar PV majorly agree on this statement and action factor norm are 86.51%.

<table>
<thead>
<tr>
<th></th>
<th>Strongly Disagree</th>
<th>Disagree</th>
<th>Undecided</th>
<th>Agree</th>
<th>Strongly Agree</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>College Students No</td>
<td>7.39%</td>
<td>7.14%</td>
<td>4.93%</td>
<td>39.90%</td>
<td>40.52%</td>
<td>100.00%</td>
</tr>
<tr>
<td>Current Installation Yes</td>
<td>2.13%</td>
<td>6.91%</td>
<td>6.91%</td>
<td>43.09%</td>
<td>40.43%</td>
<td>100.00%</td>
</tr>
<tr>
<td>Total</td>
<td>6.50%</td>
<td>7.20%</td>
<td>5.40%</td>
<td>40.50%</td>
<td>40.50%</td>
<td>100.00%</td>
</tr>
</tbody>
</table>

Data indicated that college students who installed solar PV majorly agreed on this statement and action norm factor are 83.51% and data indicated that college students who haven't installed solar PV majorly agree on this statement and action norm factor 80.42%.

In terms of action norm factor, we can see there is anonymous ??? agreement.
**Professional Assistance Factor**

In terms of Professional Assistance Factor,

<table>
<thead>
<tr>
<th>Residents</th>
<th>I need other people to assist in my decision to purchase green products</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Strongly Disagree</td>
<td>Disagree</td>
</tr>
<tr>
<td>Current Installation</td>
<td>No</td>
<td>10.91%</td>
</tr>
<tr>
<td>Yes</td>
<td>0.00%</td>
<td>20.48%</td>
</tr>
<tr>
<td>Total</td>
<td>10.00%</td>
<td>10.00%</td>
</tr>
</tbody>
</table>

Data indicated that residents who installed solar PV majorly agreed on this statement and professional assistance factor are 60.24%; Data indicated that residents who haven't installed solar PV majorly agree on this statement and professional assistance factor are 52.67%;

<table>
<thead>
<tr>
<th>College Students</th>
<th>I need other people to assist in my decision to purchase green products</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Strongly Disagree</td>
<td>Disagree</td>
</tr>
<tr>
<td>Current Installation</td>
<td>No</td>
<td>4.94%</td>
</tr>
<tr>
<td>Yes</td>
<td>0.00%</td>
<td>22.11%</td>
</tr>
<tr>
<td>Total</td>
<td>4.00%</td>
<td>27.00%</td>
</tr>
</tbody>
</table>

Data indicated that college students who installed solar PV fairly agreed on this statement and professional assistance factor 44.21%; and Data indicated that college students who haven't installed solar PV fairly agree on this statement and professional assistance factor are 40.99%.

In terms of Professional Assistance Factor, the data shows that residents are more relying for the external help while college students with higher education are less relying on the assistance.

**Cost Factor**

Cost factor is one of the major factors we usually believe that it influences solar PV adoption.

<table>
<thead>
<tr>
<th>Residents</th>
<th>I will not live in this house for long enough to recoup the cost</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Strongly Disagree</td>
<td>Disagree</td>
</tr>
<tr>
<td>Current</td>
<td>No</td>
<td>3.60%</td>
</tr>
</tbody>
</table>
Data indicated that residents who installed solar PV almost barely agreed on this statement and cost factor are 20.48%; and data indicated that residents who haven't installed solar PV somehow agree on this statement and cost factor are 45.47%

<table>
<thead>
<tr>
<th>College Students</th>
<th>I will not live in this house for long enough to recoup the cost</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Strongly Disagree</td>
<td>Disagree</td>
</tr>
<tr>
<td>Current Installation</td>
<td>No</td>
<td>4.67%</td>
</tr>
<tr>
<td></td>
<td>Yes</td>
<td>3.74%</td>
</tr>
<tr>
<td>Total</td>
<td>4.50%</td>
<td>19.40%</td>
</tr>
</tbody>
</table>

Data indicated that college students who installed solar PV barely agreed on this statement and cost factor are 21.39%; and data indicated that college students who haven't installed solar PV barely agree on this statement and cost factor are 19.68%.

CONCLUSIONS AND FUTURE STUDY

<table>
<thead>
<tr>
<th></th>
<th>Residents (N=452)</th>
<th>College Students(N=63)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Install</td>
<td>Not Install</td>
</tr>
<tr>
<td>Environmental Limit Factor</td>
<td>100%</td>
<td>66.12%</td>
</tr>
<tr>
<td>Environmental Adoption Factor</td>
<td>40.96%</td>
<td>23.36%</td>
</tr>
<tr>
<td>Price Norms Factor</td>
<td>60.24%</td>
<td>61.72%</td>
</tr>
<tr>
<td>Action Norms Factor</td>
<td>100%</td>
<td>86.51%</td>
</tr>
<tr>
<td>Professional Assistance Factor</td>
<td>60.24%</td>
<td>52.67%</td>
</tr>
<tr>
<td>Cost Factor</td>
<td>20.48%</td>
<td>45.47%</td>
</tr>
</tbody>
</table>

Based on above analysis, it is easy to conclude that most resident and student respondents agreed on environmental limit and action norms; They were partially agreeing on price norms, professional assistance; As to environmental adoption and cost factors, resident and students responds are not the same.

REFERENCES


ESTIMATING LOGISTICS AND EMISSIONS FOR FOOD DELIVERIES TO RESTAURANTS IN DOWNTOWN CHICAGO

Anthropogenic activities are affecting environmental changes, including global warming / climate change, as well as other impacts. Because cities can be highly dense population centers, they can produce amplified environmental burdens. One aspect of cities that many take for granted is food supply, distribution, and consumption. In fact, eating at restaurants is a key feature of modern society, but the supply of food to restaurants is not often given consideration, and there has not been much development or change in the logistics surrounding the food industry (Anand et al, 2012).

Some of food supplies are considered potentially hazardous substances and require a safe transport from point of production or harvest to the points of purchase before consumption. How these food substances are moved safely, on-time and with ease without contamination across the city for delivery is investigated under the umbrella of green city logistics. In city logistics, public and mass transportation are not considered among the viable solutions to lessen the adverse effect of food delivery networks such as traffic congestion, air pollution, and delivery inefficiencies. City Logistics is the industry's attempt at defining the problem and then offering solutions (Crainic & Feillet, 2015).

Toward that end, the objectives of this study were to estimate environmental emissions and to assess costs for daily food deliveries to restaurants in a large city, using Chicago as a case study. A variety of system variables were considered in our model, including: type of delivery truck (refrigerated vs. non-refrigerated); fuel economy of delivery trucks (full vs. empty); fuel economy of delivery trucks (city driving vs. highway driving); travel from food warehouse to city center (1 to 100 km); average truck speed outside downtown city center (5 to 80 km/h); travel amongst restaurants within the city center (0.1 to 5 km); average truck speed within downtown city center (1 to 20 km/h), during delivery at each restaurant, the truck engines will either idle or be shut off; time at each restaurant stop (5 to 20 min); idling at stoplights during travel within the city center (0.5 to 5 min).

Proposed baseline model was built using gasoline-powered trucks. Additional simulations were conducted using fuel ethanol (E10) and biodiesel to estimate their impacts compared to gasoline. This type of assessment is central to the growing field of study known as Green Logistics, and it can serve to help decrease environmental footprints of various supply chains which support cities.

Keywords: City logistics, Food industry, Green logistics, Green supply chain.
Materials and Methods

The goals of this project were to conduct a complete life cycle assessment and techno-economic analysis of the logistics of food delivery to all restaurants in downtown Chicago. To accomplish this, models were built using MS Excel as well as the other LCA software packages. Google Maps was used to plan the logistics for routing trucks and warehouses.

Specifically, variables which were considered included: effective work hours / day; average cargo capacity of delivery trucks; fuel economy of trucks when full; fuel economy of trucks when empty; fuel economy of trucks – city vs. highway driving; average truck speed outside city center (downtown) [5 to 80 km/h]; average truck speed within city center (downtown) [1 to 20 km/h]; during delivery at each restaurant [idling vs. shut off engine]; time at each delivery stop [5 min – 20 min]; idling at stoplights during travel within city center [0.5 to 5 min]; refrigerated trucks; non-refrigerated trucks; travel from food warehouse to city center [1 to 100 km]; travel amongst restaurants within city center [0.1 to 5 km].

These models were built to assess environmental emissions and costs for the ranges of the above variables. Additionally, they were used to simulate the effects of using various types of fuels for the trucks (i.e., gasoline, E10, and B20).

Results and Discussion

We determined, as expected, that travel distance to the city center consumed largest amount of fuel (and thus produced the greatest amount of GHG emissions). Additionally, the time spent idling at stoplights consumed considerable fuel also. In fact, if the truck engines were shut off during stops (instead of idling), fuel consumption (and thus GHG emissions) could reduced by ~20-30% (Figure 1). We also found that the type of fuel impacted consumption & emissions, and using biofuels were not always better (Figure 1).

Implications and Conclusions

This project was a case study in the application of Green Logistics. Although this work focused on Chicago, this approach to Green Logistics is widely applicable. Our next steps could include generalizing the model for use in any large city. Eventually, these types of models can be used to help optimize routing for food deliveries within cities, and can help lower environmental footprints for food companies.
Green Cities: US-Swiss Partnership

Minoo Tehrani, Alison Page, Meredith Bryden
Gabelli School of Business, Roger Williams University

Abstract

Energy is a major focus of sustainability studies. Development of non-fossil fuel and renewable energy is in the heart of sustainability research. Creation of “Green Cities”, cities with zero carbon foot print along energy, transportation, architecture, and industry activity cost chain, are the areas that define the future of our planet. This research focuses on the partnership agreement between the Swiss government and the State of Massachusetts and the challenges that government officials, business owners and employees, and educators face in order to shift and transform our cities into green and sustainable habitats.
Palm to Palm: Moving Forward

Jonathan Gomez, Hamilton Lane, 1 Presidential Blvd, Bala Cynwyd, PA 19004, (215) 609-5952, gomez.e.jonathan@gmail.com

Neil Desnoyers, Saint Joseph’s University, 5600 City Ave, Philadelphia, PA 19131, (484) 432-2767, ndesnoye@sju.edu

ABSTRACT

With the Ebola outbreak in the rearview mirror, the Kono District and Palm to Palm (P2P) are returning to what can be considered normal operations. P2P has experienced a number of successes, as well as several challenges, in the past year. These events include:

1. Obtaining a small grant from the Friends of Sierra Leone Peace Corps-affiliated organization.
2. Renewing business licenses/certifications at the local, District, and federal level.
3. The breakdown and repair of the project’s palm oil digester, a principal piece of equipment for the operation.
4. The organization of the “P2P Women’s Foundation”.
5. The theft and replacement of the project’s “power tilla” or generator.
6. The collection of rudimentary financial information.

While P2P and its stakeholders manage the daily challenges of operating a microscale sustainable economic development project, we are simultaneously attempting to plan for the future. The current plans call for raising additional funds to make investments for the long term, including obtaining office equipment and developing production technology that is appropriate for a sustainable smallholder enterprise. This paper provides updates on our efforts.

Sustainability, Sierra Leone, palm oil, palm kernel soap

INTRODUCTION

The year 2016 represented Palm to Palm’s (P2P’s) first full year of operations since 2013 due to the cessation of production related to the 2013-2015 Ebola outbreak. Although P2P sustained regular production throughout 2016, it cannot be stated that things went smoothly for P2P. The project suffered two significant setbacks to palm oil production: 1) The breakdown of the project’s palm oil digester, the principal piece of equipment for producing palm oil, and 2) the theft of the
project’s power tiller or engine for the palm oil digester. Both setbacks occurred at the tail end of the palm-oil producing season and therefore impacted the project more than if they had occurred in the off-season.

On the positive side, as noted above, the project sustained production operations for the entire year. Given the tremendous difficulties experienced over the previous two years (2014 & 2015), the importance of operating for the entirety of 2016 is a significant accomplishment: P2P survived the Ebola outbreak.

This paper provides a review of activity and outcomes for 2016 and provides a brief overview of the project’s plans for the future. The paper is organized as follows: The next section provides an overview of the project’s activity for 2016. Next comes an overview of outcomes achieved by the project during the year, followed by a section covering the project’s plans for the future. The conclusion details the lessons we learned this year.

2016 ACTIVITIES

Most of P2P’s significant activities in 2016 were related in some way to a small grant the project received from the Friends of Sierra Leone (a Peace Corps-related nonprofit) in June 2016. The Palm to Palm (P2P) Project was awarded a Project Funds Grant in the amount of $1,400 (or about SLL 8.5M) by the Friends of Sierra Leone. Since P2P only requested SLL 1.4M (~$210) in our Project Funds Grant application, we were pleasantly surprised by the level of support and trust FoSL placed in our small project. This section of the paper details the project’s significant activities for 2016 and how these activities were largely tied to the grant. The below information comes largely from the grant report submitted by P2P to Friends of Sierra Leone [1].

The Project Funds Grant funds were spent in five different areas:

1. P2P License and Certification Renewals (original request): $ 257.63 (SLL 1.7M)
2. Palm Oil Machine (Digester) repair: $ 724.62 (SLL 4.4M)
3. P2P Project Motorbike license and insurance: $ 125.16 (SLL 0.8M)
4. Used Power Tiller (Engine) for Palm Oil Machine: $ 255.59 (SLL 1.7M)
5. Western Union money transfer fees: $ 37.00

Total grant expenditures: $1,400.00

Following are details of each of the project’s six significant activities for the year. Four of the six significant activities were directly enabled by the Friends of Sierra Leone grant.

P2P License and Certification Renewals

As the only item mentioned in our original Project Funds Grant application, P2P spent SLL 1.7M ($257.63) to renew appropriate certifications. Specifically, this involved renewing business licenses and certifications with the City Council, the Social Welfare Office, the Sierra Leone Traders Union, and the Ministry of Agriculture to allow P2P to once again become a fully-recognized entity in Sierra Leone. In addition, Labor Cards were obtained for ten (10) workers. P2P is already planning to renew these items again for the current year (2017).
Palm Oil Machine (Digester) repair
Unfortunately, shortly after P2P was awarded the Project Funds Grant, the project’s Palm Oil Machine (or Palm Oil Digester) broke down for the first time since it was purchased in 2012. The Palm Oil Machine is P2P’s principal piece of equipment and is integral to the production of palm oil, as it extracts the palm oil from the flesh of the palm fruit. The specific cause of the breakdown was the fact that the pinor part broke. This breakdown necessitated bringing technician(s) and parts from Freetown to repair the machine. In total, the repair cost SLL 4.4M ($724.62). Since the repair, the machine has been working just fine, and we expect it will continue to do so for some time to come.

P2P Project Motorbike License and Insurance
For some time, the project has owned a motorbike to transport people involved with the project. Registration and insurance were obtained for the motorbike (SLL 0.8M [$125.16]).

Purchase of used Power Tiller (Engine for Palm Oil Machine [Digester])
Unfortunately, on the evening of July 1st, a small group of criminals attacked the project’s security guard and stole the project’s “power tilla” or the engine that powers the Palm Oil Machine (Digester). The project borrowed a replacement from another business and was able to start producing palm oil again fairly quickly, but this was only a short-term solution. The cost of a new replacement power tiller was ~SLL7.5M (~$1,140) which was out of the project’s reach, so a used machine was purchased as a replacement. The total cost of the used power tiller (including repair, transportation, and other expenses) was ~SLL 5.0M (~$770), towards which the remaining balance of P2P’s Project Funds Grant (~SLL 1.7M [~$255]) was used. The balance owed on the replacement power tiller was paid for by donations from the project’s two private supporters and funds from the project’s operations.

Palm to Palm Women’s Foundation
2016 saw the formation of the “Palm to Palm Women’s Foundation”. According to P2P’s local manager (D. Somoyah) [2], “This women[‘s] group was form[ed] to engage [K]ono women in agricultural activities in small scale farming, vegetables garden and to build their capacity for self-reliance and families.” The group primarily engaged in two activities during the year:

1. Gari production: Cassava is purchased at the local market and processed by the women into gari, a staple of African cuisine. The gari is then sold to locals and at the local market.
2. Fish processing: Fish are purchased at the local market and processed. The processed fish is then sold to locals and at the local market.

Plans for the women’s foundation call for farming cassava for gari production and growing vegetables.

Production and Financial Information
2016 is the first full year for which the project was able to record production and financial information. Given the difficulties in doing so (lack of office equipment, lack of Internet access, some language issues, reliance on emailed updates providing the information, etc.) the
information collected is rudimentary in nature. As with other areas of the project, however, we expect that the quantity and quality of information collected will grow over time.

The above activities constitute the major activities of P2P for 2016 that occurred in addition to the project’s principal activities of producing palm oil, palm kernel soap, and gari.

**2016 OUTCOMES**

P2P’s primary outcomes for the year fall into three categories: Employment, production, and revenue. Each category of activity is important in measuring the project’s current and future impacts.

P2P employed approximately 18-20 local Sierra Leoneans for the duration of 2016 for the production and sale of palm oil and palm kernel soap. In addition, approximately 25 women were involved in the Palm to Palm Women’s Foundation for at least part of the year processing cassava into gari and processing fish. These employment figures represent some progress over 2015 towards one of P2P’s twin goals (“… to provide employment and self-determination to the people of Kono in a sustainable manner…”).

The primary products produced by P2P in 2016 are palm oil, palm kernel soap, and gari. The project produced and sold a little over 260 “battas”, or containers, of palm oil. A batta holds five gallons of palm oil, so this represents a little more than 1,300 gallons of palm oil. In addition, we produced and sold in excess of 26,000 bars of palm kernel soap during the year. Finally, a little over 200 bags of gari were produced and sold by the Women’s Foundation. The number of bags of fish processed and sold was not recorded. Our plans call for, with proper management and additional investment, these quantities to increase in future years. Increased production and sales will require hiring additional workers, thereby providing increased support to the people of Kono.

P2P’s production and sales activities resulted in just over SLL 70M in revenues for 2016. Given fluctuations in the exchange rate over the course of the year, this represents a little more than $11,000 in revenue. This figure would have been slightly higher if the breakdown of the palm oil digester and the theft of the power tiller had not occurred: The breakdown of the palm oil digester meant that unprocessed palm fruit on hand spoiled instead of generating additional revenue, and the loss of the power tiller caused some loss of production. In addition, production and revenue results were not captured for October 2016 resulting in an understatement of full-year results.

None of the above information (employment, production, and revenue) demonstrates that P2P currently has a massive impact on the Kono region. But the importance of the project successfully operating for a full year after the Ebola outbreak and with the disruptions experienced cannot be overstated. Our expectation is that 2016 is a year on which we can build going forward.

**THE FUTURE**
Our plans for the future of the project consist of additional investments to continue what we expect will be the steady growth of P2P. These additional investments will be in the areas of facilities, transportation, production technologies, sustainability, information, and people.

Investments in facilities fall into three categories: office equipment, security, and production-related improvements. P2P needs office equipment (computers, printers, copy machine, internet access) to facilitate managing the project and record-keeping. Security-related facility improvements are being investigated after the theft of the power tiller. Production-related improvements include renovation(s) that will facilitate increased production.

A significant area of need is transportation. The project currently lacks a dedicated vehicle to transport raw materials (palm fruit, cassava, etc.) to the “factory” and finished goods (palm oil, soap, and gari) to the market. The purchase of an appropriate vehicle will benefit the project greatly.

P2P seeks to both increase production capacity and increase production efficiency by investing in additional production capabilities. As we expressed in an earlier paper [3], it is our desire to develop and/or acquire “appropriate technology”. Appropriate technology is technology that combines scientific and indigenous knowledge and can be built indigenously so that the locals develop and maintain social capital. While the project has found some information [4] about appropriate technology that may be helpful, additional information is required to allow us to formulate an action plan in this area.

The two improvements in the area of sustainability that are reasonable next steps are:

1. The location or design and implementation of a wastewater system to return water used during production to the same or higher quality as its original state. This was mentioned in a previous paper as action meeting sustainable criteria [3].
2. A method of recycling or composting the pulp that is left after the palm oil is pressed out of the flesh of the palm fruit.

As the quality and quantity of production and financial information collected by the project grows, we will seek to develop or obtain improved recordkeeping system(s). Currently the project stakeholders rely on the project manager to manually collect and email production and financial information to the project stakeholders. The information collected and stored is therefore rudimentary. In the future we expect to locate or develop an inexpensive web-based information system. This will reduce data entry and allow all stakeholders to have simultaneous access to project information.

Finally, P2P’s stakeholders are making investments in the people involved in the project. In the last year, the project’s two primary private benefactors have provided support for the local project manager to attend college. In addition, and following the theft of the power tiller in July, one of the project’s primary private benefactors has begun supplementing the security guard’s salary—this was requested by the security guard as a condition of remaining on the job.
CONCLUSION

We are cautiously optimistic about P2P’s future. The primary reasons for our optimism are:

1. Operating for the entirety of 2016 demonstrates that P2P has recovered from the disruptions of the 2013-2015 Ebola outbreak.
2. Recovering from two smaller incidents (palm oil digester breakdown and theft of power tiller) that occurred in 2016 demonstrates perseverance, especially on the part of the local manager.
3. Employees (especially the local manager) have demonstrated they are committed to the long-term success of the project.
4. A growing number of Kono residents rely on P2P products on a daily, or at least weekly, basis.

With sustained growth, the positive impact of P2P on the people of Kono and Sierra Leone will only increase. This was the goal of the project’s stakeholders at the project’s founding, and it is still our goal today.

The authors wish to thank the following individuals and entities for support with this project: David Somoyah (P2P—Kono), Jim Hanson (Friends of Sierra Leone), Alejandro Lucena Mir (P2P—Spain), Friends of Sierra Leone.
REFERENCES


ROC-ing the Grid: the Unintended Consequences of Northern Ireland’s Renewable Obligation Credit Policy.

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Abstract

In 2005 Northern Ireland (NI) introduced the renewable obligation certificate (ROC) policy, which was designed to increase the levels of renewable generation in the country. While the ROC was successful in encouraging the uptake of renewable generation technology, the scale at which small scale and microgeneration (SMG) was incorporated to the power system was much larger than anticipated. This increase in the level of SMG renewable generation in NI has had an unforeseen impact on the electricity system, including operational and investment requirements. This paper reviews the impacts of the ROC policy on the amount of SMG, and how the number of SMG connections have impacted NI's Power grid. We caution against a further increase in the level of uncontrollable SMG connected to the power system, and our paper concludes with a recommended policy agenda.

Key words: Electricity Network; Power Grid; Wind; Renewable Energy; Delivery; Learning
Sustainability & Corporate Social Responsibility: The Case of Starbucks Corporation

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Abstract
This research investigates the corporate social responsibly (CSR), ethical conducts, and the sustainability strategies of Starbucks Corporation. The research explores the impacts of such conducts and strategies along the activity cost chain and different stakeholders of the corporation, such as suppliers, employees, and customers. In addition, the research examines Starbucks Corporation’s community-based initiatives. The final part of the research assesses the impacts of such conducts and strategies on competitive advantages of Starbucks Corporation.
The Levelized Cost of Carbon: A Practical, if Imperfect, Method to Compare CO₂ Abatement Projects for Investment Decision Making

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Many governments and organizations, including Massachusetts Department of Transportation (MassDOT), are required to reduce Greenhouse gas (GHG) emissions and would like to do this in an efficient and cost-effective manner. However, resources available to agencies are limited both in terms of the ability to invest in GHG reduction projects and in terms of time and resources available for making investment and policy decisions. This research presents a GHG-reduction cost-effectiveness metric and investigates the theoretical and practical implications of using a cost-effectiveness metric to rank the projects.

We present a metric we call the Levelized Cost of Carbon (LCC), which provides a cost per ton of CO₂ avoided. It accounts correctly for the time value of money, as well as for a possibly changing value of reducing GHGs through time. We develop the formula for the levelized cost per ton of CO₂ avoided. We define LCC as the constant cost per unit of CO₂ avoided that equates the net present value of savings and costs. This definition is shown to encompass the most common definitions in the literature, which do not carefully account for the time value of emissions reductions. The LCC can be used in decision making by comparing it to the Social Cost of Carbon (SCC), or to any other appropriate value, to determine whether a project should be invested in or not. Based on the perspective of agency’s decision makers, Knapsack formulation can be used to frame the need to achieve a given climate target at the lowest cost (cost minimization) or it can be used to frame it as an allocation of fixed budget dedicated to reducing emissions (emissions reduction maximization).

In calculating the net costs of GHG-reduction projects, all the benefits should be monetized and subtracted from the costs which are extremely challenging to do in practice. Because an accurate estimate of the full social welfare benefits of an alternative would require considering the dynamics of the economy. In this study, we focus on CO₂ which is by far the most important GHG in transportation. However, in some applications, other gasses are equally or more important. Incorporating multiple gasses adds new complexities since different gasses have different lifetimes and different warming effects. The most widely adopted methodology is to calculate emissions in terms of CO₂ equivalences.

Finally, we conclude that it is not generally valid to use this metric - or any other cost-effectiveness metric to rank projects. However, we outline the assumptions under which it is valid to use LCC to compare projects. In addition, we provide a methodology for communicating the comparison of projects for which LCC cannot be used on its own and Pareto Frontier analysis needs to be incorporated.
Exploring the Association between Regional Development Index and Hospital WEB Site Quality: A Study in the Mediterranean Region of Turkey

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ABSTRACT

The main purpose of this study is to investigate the relationship between Regional Index of Development (belong to cities which the hospitals work in) and Total Web Score (or hospital website quality). The findings of this study will further help healthcare administrators, web designer and healthcare politicians to use the websites of their hospitals efficiently and properly as a tool of marketing. The results supported the hypothesis of “The regional development index affects hospital web sites quality.”

Key Words: Health care management, hospital website, internet technology, information technology, health technology.

INTRODUCTION

Using the internet and communication technology provides the hospitals with some benefits: to provide more qualified services, to present valuable information for their patients, to decline the expenditures, to have direct interaction with patients, to save their time, to increase efficiency, and finally to enable the hospitals to overcome their competitors (Rafe and Monfaredzadeh, 2012).

The Internet has become an important resource for information and exists as the widespread used tool for people who are seeking for the desired healthcare. While 61% of adults retrieved the health information online in the United States, 55% of them looked for information about the different dimensions of healthcare (online lab results, new treatment methods etc.).
However, the quality of these websites and their contents are not clear or reliable (Lin, Hsiang-Wen, et al., 2013).

There are some studies to evaluate websites, Liu et al. (2011) examined the websites of general hospitals in China. The majority of hospitals performed well in the website content, while performed normally in the design and functions of website; with respect to the management as well usage of website, only a small number of hospitals showed a satisfactory performance. Gruca and Wakefield (2004), Norum and Moen (2004) suggested that web site developments, since the management of a web site is a process that requires continuous updating and dedication. There were various studies on analysis of the hospital websites in Turkey. For instance, in the study of Uğurluoğlu (2009), the prevalence of websites of public and private hospitals, types of information to be contained in these websites together with the relation between these information and corporate ownership. On the other hand, the study of Özkan and Çağltay (2014), it was examined if the largest two education and training hospitals have a good design. The aim of the study of Köksal et al (2012) is to evaluate the content of webpages within the framework of health communication according to public and private hospitals. According to this study web pages as health communication tool were used by private hospitals effectively. Çolak et al. (2004) examined the websites of private hospitals in Turkey in 2004 according to selected criteria. Since the information on the hospital websites do not have a standard structure, there are differences and the patients were found that they cannot reach the information they need.

Like any country, the regions have quite different level of development in terms of socio-economic conditions in Turkey. In order to provide a balanced development among the regions, the planners focus on the determination of the level of development with reference to measurable and relatively comparable socio-economic indicators (Albayrak, 2005).

It is considered that the content of the hospital websites is related with the level of development of the region where the hospital is in. The results of the research to be conducted support the judgement. The aim of comparing the hospitals with reference to the regions is to demonstrate the ways to be followed to develop websites having important role in the healthcare sector, to provide awareness on the items to be included in the websites and to contribute the websites to reach their differences to an acceptable level.

The Regional Development Index to be referred in this study was calculated by the experts of İş Bank by considering 49 criteria. 32 of those criteria reflect the economic activity and other 17 reflect the level of social development. While the development index of the region
being calculated, as economic development criteria the population, net migration, tax revenue to be collected, investment incentives, number of companies in ISO 1000, number of companies in Export 1000, power consumption, number of trucks, number of tractors, export, import, number of total companies to be established, saving deposits, number of bank branches, cash credits, rates of non-performing loans, non-cash credits, number of ATMs, number of POS devices, number of member companies, number of interactive banking clients, green production, animal production, tourism, population density, population development, percentage of the population under 15, number of cars, rate of labor force, unemployment rate, public investments and number of entrepreneurs were used. As social development criteria air pollution, rate of house owners, number of medical doctors, number of hospitals, number of beds, infant mortality, number of movie audience, house sales, total taking off-landing numbers, number of airway passengers, load to be carried by airway, innovation, number of students in universities and higher schools, number of instructors, number of ADSL subscribers, number of land lines, number of mobile phones were considered (Gül and Çevik, 2015).

METHOD

Purpose and Research Hypotheses

H1= The regional development index affects hospital web sites quality.

The main purpose of this study is to investigate the relationship between Regional Index of Development (belong to cities which the hospitals work in) and Total Web Score (or hospital website quality). The findings of this study will further help healthcare administrators, web designer and healthcare politicians to use the websites of their hospitals efficiently and properly as a tool of marketing.

Sample and Data Collecting

The sample consists of all hospital websites which belongs to private general hospitals, private speciality hospitals and foundation-university hospitals in the region of Mediterranean in Turkey. Under the scope of this research 78 website had been examined according to checklist that including 45 item. These items were selected from the research database which investigated on the websites of the hospitals in different countries (The descriptive data of the hospitals has collected from secondary resources (Turkish Statistical Institute, city governorship, Social Security Institution). There are total 83 private general hospitals, private specialty hospitals and foundation-university hospitals in the region of Mediterranean. Nevertheless 5 hospital’s websites are not available (due to out of service or broken link).
This cross sectional survey based study done on the hospitals’ websites which operate in Turkey’s region of Mediterranean. Study aims all private hospitals (private general, private specialty and foundation-university hospital).

A questionnaire was designed comprising of 2 sections. The first section consists of descriptive details of the hospitals (status and bed size) and second section contains questions regarding website quality scores. All questions had two choices (0-not available, 1-available). Total 45 items are related hospital characteristics- logo, mission, vision, ISO and accreditation, email address, map, departmental info, doctors’ background, insurance info, online appointment, online lab results, patients’ rights etc. Total web scores were calculated by the sum of these 45 items of the websites.


Data Analysis

Statistical analysis was performed using SPSS (IBM SPSS Statistics 20). Data were expressed in frequencies, mean and percentages.

The relationship between dependent and independent research variables was tested by using Spearman’s Rank Correlation analysis. We need to perform some normality checks for the two variables (Index of Development and Total Web Score). According to Boxplots of the data, Index of Development is fairly consistent with one from a normal distribution. We do have concerns over the normality of our data and should continue with a Spearman’s correlation analysis.

Spearman’s rank correlation coefficient is a nonparametric (distribution-free) rank statistic proposed as a measure of the strength of the association between two variables (Hauke, J., & Kossowski, T., 2011).
FINDINGS

Hospital Characteristic were shown in Table 1, The majority of the hospitals were private general (84,6 percent) working on all specialty branches, the most of these have less than 50 hospital beds (42,3 percent).

Table 1. Hospital Characteristic

<table>
<thead>
<tr>
<th>Hospital Status</th>
<th>f</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Private General</td>
<td>66</td>
<td>84,6</td>
</tr>
<tr>
<td>Private Speciality Hospital</td>
<td>10</td>
<td>12,8</td>
</tr>
<tr>
<td>Foundation-University Hospital</td>
<td>2</td>
<td>2,6</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bed Size</th>
<th>f</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;50</td>
<td>33</td>
<td>42,3</td>
</tr>
<tr>
<td>51-100</td>
<td>29</td>
<td>37,2</td>
</tr>
<tr>
<td>101-150</td>
<td>12</td>
<td>15,4</td>
</tr>
<tr>
<td>151-200</td>
<td>3</td>
<td>3,8</td>
</tr>
<tr>
<td>&gt;200</td>
<td>1</td>
<td>1,3</td>
</tr>
<tr>
<td>Total</td>
<td>78</td>
<td>100,0</td>
</tr>
</tbody>
</table>

As seen on Table 2 the mean of the Index of Development is 2,6 and the mean of the total web score is 19,4.

Table 2. Descriptive Statistics of Index of Development of the Cities Where Hospitals Work in and Total Web Score

<table>
<thead>
<tr>
<th></th>
<th>N</th>
<th>Minimum</th>
<th>Maximum</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>Index Of Development</td>
<td>78</td>
<td>-1,57</td>
<td>7,00</td>
<td>2,5855</td>
<td>3,21762</td>
</tr>
<tr>
<td>Total Web Score</td>
<td>78</td>
<td>9,00</td>
<td>34,00</td>
<td>19,3590</td>
<td>4,89361</td>
</tr>
<tr>
<td>Valid N (listwise)</td>
<td>78</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

When all websites have been evaluated for the availability of the items, the following percentages (Table 3) were found. Hospital name on the website ranks 1\(^{th}\)(98, 7 percent) and the social needs like ATM, helicopter and hairdresser rank 45\(^{th}\) with the percent of 1,30, and 2,60.

Table 3. Availability of the Each Item on Websites

<table>
<thead>
<tr>
<th>Website Item</th>
<th>%</th>
<th>Website Item</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hospital Name On Web</td>
<td>98,70%</td>
<td>Online Lab Password</td>
<td>23,10%</td>
</tr>
<tr>
<td>Logo</td>
<td>88,50%</td>
<td>Visit Days Time</td>
<td>73,10%</td>
</tr>
<tr>
<td>History</td>
<td>75,60%</td>
<td>Second Language</td>
<td>26,90%</td>
</tr>
<tr>
<td>Adress</td>
<td>94,90%</td>
<td>Foreing Patient Link</td>
<td>7,70%</td>
</tr>
<tr>
<td>Transportation Type</td>
<td>5,10%</td>
<td>ATM</td>
<td>1,30%</td>
</tr>
</tbody>
</table>
### Table 3. Availability of the Each Item on Websites (continuous)

<table>
<thead>
<tr>
<th>Website Item</th>
<th>%</th>
<th>Website Item</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Map</td>
<td>85.90%</td>
<td>Cafe</td>
<td>6.40%</td>
</tr>
<tr>
<td>Mission Vision</td>
<td>73.10%</td>
<td>Place Worship</td>
<td>5.10%</td>
</tr>
<tr>
<td>PhoneNumber</td>
<td>92.30%</td>
<td>Hair Dresser</td>
<td>2.60%</td>
</tr>
<tr>
<td>CallCenter</td>
<td>51.30%</td>
<td>Parking Area</td>
<td>5.10%</td>
</tr>
<tr>
<td>Email</td>
<td>83.30%</td>
<td>Helicopter</td>
<td>1.30%</td>
</tr>
<tr>
<td>Departments</td>
<td>92.30%</td>
<td>Patient Rights</td>
<td>47.40%</td>
</tr>
<tr>
<td>Departmental Phone Numbers</td>
<td>3.80%</td>
<td>ISO</td>
<td>3.80%</td>
</tr>
<tr>
<td>VirtualTour</td>
<td>20.50%</td>
<td>Accreditation</td>
<td>6.40%</td>
</tr>
<tr>
<td>PromotionFilm</td>
<td>14.10%</td>
<td>Search Engine</td>
<td>12.80%</td>
</tr>
<tr>
<td>Insurance Type</td>
<td>82.10%</td>
<td>Announcement</td>
<td>55.10%</td>
</tr>
<tr>
<td>Doctors Name Alphabetical</td>
<td>28.20%</td>
<td>Media</td>
<td>29.50%</td>
</tr>
<tr>
<td>Doctors Name Departmental</td>
<td>73.10%</td>
<td>Live Chat</td>
<td>5.10%</td>
</tr>
<tr>
<td>Doctors CV</td>
<td>56.40%</td>
<td>Communication Form</td>
<td>87.20%</td>
</tr>
<tr>
<td>Doctors Communication</td>
<td>20.50%</td>
<td>Social Media</td>
<td>70.50%</td>
</tr>
<tr>
<td>Doctor Web</td>
<td>20.50%</td>
<td>Update Date</td>
<td>51.30%</td>
</tr>
<tr>
<td>Online Appointment</td>
<td>65.40%</td>
<td>Copyright</td>
<td>57.70%</td>
</tr>
<tr>
<td>Online Lab Result</td>
<td>64.10%</td>
<td>Web Designer</td>
<td>46.20%</td>
</tr>
<tr>
<td>Multilingual Support</td>
<td>20.50%</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### Hypothesis Test

Table 4 shows the relationship between two variables (Index of Development and Total Web Score).

**Table 4. Spearman’s Rank Correlation**

<table>
<thead>
<tr>
<th></th>
<th><strong>Index Of Development</strong></th>
<th><strong>Total Web Score</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Index Of Development</td>
<td>Correlation Coefficient</td>
<td>1.000</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td></td>
<td>0.429*</td>
</tr>
<tr>
<td>N</td>
<td></td>
<td>78</td>
</tr>
<tr>
<td>Total Web Score</td>
<td>Correlation Coefficient</td>
<td>0.429**</td>
</tr>
<tr>
<td>Sig. (2-tailed)</td>
<td></td>
<td>0.000</td>
</tr>
<tr>
<td>N</td>
<td></td>
<td>78</td>
</tr>
</tbody>
</table>

*Correlation is significant at the 0.01 level (2-tailed).

The significant Spearman’s correlation coefficient value of 0.429 appears to be a moderate positive correlation between the two variables (N=78, r=0.43, p<.000). Index of Development and Total Web Score are related variables. When the index of development increases total web
score will tend to increases and vice versa. This result supported research hypothesis 1 “The regional development index affects hospital web sites quality.”

RESULTS AND SUGGESTIONS

In this study the relationship between two important variables were investigated. Development Index is significant indicator including many dimensions of a region or a city. In the past 10 years global trade in goods and services almost doubled—reaching nearly $24 trillion in 2014, up from $13 trillion in 2005. The digital components of these flows have also been increasing (Human Development Report, 2015). Actually technological improvements bring about the importance of the web sites and internet. The roles of these tools on the achievement of the hospital have been evaluated various researchers.

According to a survey by the Pew Internet and American Life Project (May 17, 2005), eight out of ten Internet users have used the Internet to find health care information in sixteen different topic areas, including details on doctors and hospitals. And the internet and web sites play a major role in the reforms of healthcare systems (Eysenbach, 2000) and they have great potential to transform the core processes of healthcare entities (Goldsmith, 2000; Pare´ and Sicotte, 2001). In the healthcare area the websites can be used to reduce costs, to improve efficiency and productivity, to provide quality services, to achieve greater organizational flexibility and, especially, to facilitate and improve communications within the organization and the actors of the sector (Hatcher, 2001; Newell, 2001; Orr et al., 2001; Gonzalez et al., 2006, Garcia-Lacalle et al, 2010).

The use of the internet has given patients access to a huge amount of information at a time when an increasing number of patients are adopting an active role in their health and becoming more involved in their treatment (Mears and Sweeney, 2000; Sanchez, 2000). Hospital websites are useful virtual spaces where patients can gain health and medical knowledge as well as locate healthcare professionals (Gefen, Karahanna, and Straub, 2003).

In summary many patients and their family members use many different resources in order to obtain information about healthcare and their health data for example doctors’ cv, name, hospitals’ clinics, new notices, diagnosis and treatment alternatives and prices of the services. But some of these resources are not clearly, not up to date or deficient. It can be forgivable level in the developed cities in Turkey. Still looking at the web scores of the hospitals largely they are missing from some needful information. To remove the differences among the websites some standards can be launched out. These websites need to be checked by governmental authority. Hospital administrators should know the importance of the websites as a marketing tool and a bridge between health care providers and patients.
Limitations

This study is effective in evaluating a hospital’s websites within the regional social-economic framework. It was limited to local data and regional private hospitals. In the future, a study should be developed with the participation of hospital management, and patient. It should aim at all public and private hospitals’ websites.

References


HEALTH INFORMATION TECHNOLOGY IN NURSING: VIEWS AND ATTITUDES OF NURSE MANAGERS

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ABSTRACT

Aim: Aim of this study was to determine nurse managers’ views and attitudes towards health information technology.

Method: This study was planned as a mixed methods study. Sample of the study consisted of 52 nurse managers. Data-collection tools were: “Personal Information Form,” “Health Information Technology Using Questionnaire,” and “Semi-Structured Questionnaire.” Content analysis was used for data obtained from face-to-face interviews, and data obtained from other data collection tools were analyzed by frequency, percentage distributions, means, and standard deviations.

Results: Respondents noted strengths of health information technology, such as easing workflow and minimizing medication errors through better documentation. Perceived weaknesses included long waits to obtain patients’ medications when the system was busy, and time lost entering information into the system. Mean score for attitudes about health information technology was 4.90 out of 7 (SD±0.90).

Conclusion: Nurse managers experienced difficulties with learning and perceptions about the system, teaching a new system to team members, and adapting when a new system replaced the old one.

Keywords: Communication; Health Service Management; Informatics; Information Technology; Nursing; Nursing Care; Nursing Roles.
REFERENCES


1. Problem and Contribution

The purpose of this study is to determine individual and organizational factors that affect the attitudes of hospital managers towards health information technologies. Survey data was obtained by an online survey instrument. It was hypothesized that a variety of individual and organizational factors were important in using and affecting the attitudes of health care managers against health information technologies in hospitals.

Health information technologies such as electronic patient records, prescriptions, order systems are believed to increase productivity, reduce medical errors and healthcare costs [1]. Well-integrated HIT has the potential to improve patient care [2]. Successful adoption requires managerial support and positive attitudes from the technology users.

2. Research Methodology

This descriptive and cross-sectional study was carried out to determine individual and organizational characteristics affecting the attitude of hospital managers against HIT use in their hospitals. The sample consists of hospital managers working in general, specialty and training hospitals of Ministry of Health (MoH) in Turkey. Those hospital managers holding the position of hospital director, administrator and medical director were included in the sample since current regulations give more authority this group of hospital managers to decide HIT investment and do regulations to use HIT more efficiently. At the time of this study was conducted, there were 2720 hospital managers holding these positions at 832 MoH hospitals all around Turkey.

3. Findings

The effects of individual and organizational characteristics on the computer, internet and overall information technology utilization were examined by using a series of regression analysis. The results showed that some individual and organizational factors were statistically significant in using and affecting the attitudes of health care managers against health information technology. The variables of age, years of computer usage at home, hospital status, hospital region, having information technology instructions and job position were found to be significant individual and organizational characteristics having significant effect on health information technology use.

Key Words: Health information technologies, information technology, health information technology adoption, adoption models, attitude.
2

Introduction
A large volume of research has examined why users accept and use IT, with theories such as the technology acceptance model [3] and unified theory of IT acceptance and usage [4]. Throughout the years researchers also proposed various models to further explain the factors associated with IT adoption, such as Motivational Model (MM) [5], Combined TAM and TPB (C-TAM-TPB) [6], Composite Information Technology Adoption Model (CITAM) [7], Model of PC Utilization (MPCU), TAM2 and TAM3 [8, 9] as extensions of TAM. These models share the characteristic of technology adoption and sub-components playing a role in the adoption of technology. In TAM and TAM2, perceived usefulness, perceived ease of use, subjective norms, experience, voluntariness, image, job relevance, output quality, result demonstrability are discussed. In TRA, subjective norms and attitudes were focused on and TPB dealt with attitude, subjective norm and perceived behavioral control. IDT emphasizes relative advantage, compatibility, complexity, observability, trialability. Moore and Benbasat [10] five attributes from Rogers’ model (1995) and two additional constructs (image and voluntariness of use) are identified. Compeau and Higgins [11] to determine the usage apply SCT by Bandura [12] to information systems. In addition, eight important constructs (encouragement by others, others’ use, support, self-efficacy, performance outcome expectations, personal outcome expectations, affect and anxiety) are found that have a role on technology behavior. MM also stems from psychology to explain behavior. Davis et al. [5] applies this model to the technology adoption and use. Triandis [13] to predict PC usage behavior adjust MPCU by Thompson et al. [14] from the theory of attitudes and behavior. Social factors affect, perceived consequences (complexity, job-fit, long-term consequences of use), facilitating conditions and habits are significant. UTAUT by Venkatesh et al. [4] and then UTAUT2 [15] integrates above theories and models to measure user intention and usage on technology.

HIT became a focus of many researches in 2000s, and it has been continuing to be one of the most important topics discussed in health sector since it has a very close relationship with the hot topics of health care sector such as organizational behavior, service quality and performance, human resources management, financing and service cost, competition advantage, profitability and efficiency. It is essential for a health organization to determine optimum resource combinations to minimize its cost by maximizing its outputs. Production process defines how resources or inputs are processed into goods and services, and there are many medical and non-medical resources that are needed in this process such as personnel, building or computers to produce outpatient and inpatient services. HIT is considered as one of these inputs. Nevertheless, it might be an important inefficiency reason in health care organizations if health care personnel because of adaptation problems do not use HIT efficiently. Inefficient use of HIT may even increase the inefficient use of other resources such as personnel and medical supplies since efficient share of information is not the case between and among the units and services.

Decisions on investments for ITs also must consider other stakeholders of health sector such as medical service providers, patients, health insurance organizations, health care policies and even World Health Organization. These decisions are complex and comprehensive. However, the benefits that would be gained from IT depend on the success of efficiency and profitability of IT investments. For this reason, determine factors affecting adaptation to HIT negatively, taking necessary measures to lessen the adverse effects of barriers, and improving HIT success by increasing efficient use are all important to lead health care organizations and managers use their limited resources efficiently.

Research Hypotheses
H1: Individual characteristics of hospital managers affect the attitude of managers against computer use.
H2: Organizational characteristics of hospitals affect the attitude of hospital managers against computer use.
H3: Individual characteristics of hospital managers affect the attitude of managers against internet use.
H4: Organizational characteristics of hospitals affect the attitude of hospital managers against internet use.
H5: Individual characteristics of hospital managers affect the attitude of managers against HITs.
H6: Organizational characteristics of hospitals affect the attitude of hospital managers against HITs.

Sample
The sample consists of hospital managers working in general, specialty and training hospitals of Ministry of Health (MoH) in Turkey. Those hospital managers holding the position of hospital director, administrator and medical director were included in the sample since current regulations give more authority this group of hospital managers to decide HIT investment and do regulations to use HIT more efficiently. At the time of this study was conducted, there were...
Data Collection Tool and Study Variables
Web based data collection instrument was adopted from the revised version of questionnaire titled “The Factors Affecting Information Technology Use” developed by Hikmet (1999). The original questionnaire contained 69 items (measuring computer use at work, computer use at home, internet use at home, and internet use at work), devised to capture factors associated with the attitudes of IT users and their HIT use intentions. Original questionnaire needed revision since some of the items used were not relevant to Turkey and the characteristics of the Turkish Health Care System. Expert reviews were used to test the content validity of the questionnaire. Experts were selected from individuals who were responsible managers for hospital computing departments and various other duties in MoH hospitals. The reviewers suggested that the original questionnaire to be revised by removing some of the irrelevant items and re-wording of some others for clarity. The revised questionnaire then was pilot tested among 30 managers who were hospital and medical directors, hospital administrators, and deputies working for MoH who did not have any conflict of interest concerning HIT administration in the targeted hospitals. Results of the pilot study suggested that the revised questionnaire could be deployed for this study.

Independent individual variables of the study were determined as gender, age, education status, marital status, monthly income, job position, computer ownership at home, years of using internet at home, and having certificate or training on ITs while organizational variables were hospital status, number of beds, having a separate computing department, outsourcing computing services and having written directives on using ITs at hospital. The attitudes of health care managers against computer use, internet use, and HIT itself.

Data Analysis
The relationship between dependent and independent research variables was tested by using stepwise multiple regression analysis. The attitudes against HITs were measured by three subcategories that were internet use, computer use, and itself HIT. The arithmetic means of the questions under each category were used as the total attitude score of each respondent against relevant category. The effects of categorical independent variables on dependent variables were tested by creating dummy variables in regression analysis equations.

Findings
Respondent Characteristics
The socio-demographic characteristics of the respondents were shown in Table 1. The majority of the respondents were male (52.9 percent), in mid-ages (between 31-40 years age, 56.9 percent), graduated from a 4-years university program (54.2 percent), and married (88.9 percent). The majority of the respondents were hospital administrators (71.4 percent). It is interestingly good finding that almost half of the respondents (50.8 percent) stated that they had owned IT certification or attended IT training.

<table>
<thead>
<tr>
<th>Table 1. Socio-Demographic Characteristics of Hospital Managers</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gender</td>
</tr>
<tr>
<td>-------------------</td>
</tr>
<tr>
<td>Female</td>
</tr>
<tr>
<td>Male</td>
</tr>
<tr>
<td>Age</td>
</tr>
<tr>
<td>30 years old and younger</td>
</tr>
<tr>
<td>31-40 years old</td>
</tr>
<tr>
<td>41-50 years old</td>
</tr>
<tr>
<td>51 years old and older</td>
</tr>
<tr>
<td>Education</td>
</tr>
<tr>
<td>High School</td>
</tr>
<tr>
<td>Graduate</td>
</tr>
<tr>
<td>Post Graduate</td>
</tr>
<tr>
<td>Marital Status</td>
</tr>
<tr>
<td>Married</td>
</tr>
<tr>
<td>Single</td>
</tr>
</tbody>
</table>

2720 hospital managers holding these positions at 832 MoH hospitals all around Turkey.
Hospital Characteristics

The characteristics of hospitals where the respondent hospital managers were working were provided in Table 2. The big majority of the managers were working at general hospitals providing a wide range of health care services to wide range of patients in their regions. 93,1% of the respondents stated that there was an IT department at their hospitals. However, only 48,7% of respondents said that their IT department prepared written IT instruction to make available them.

Table 2. Descriptive Characteristics of Hospitals

<table>
<thead>
<tr>
<th>Status of Hospital</th>
<th>f</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
<td>327</td>
<td>86,5</td>
</tr>
<tr>
<td>Specialty</td>
<td>21</td>
<td>5,6</td>
</tr>
<tr>
<td>Education and Research</td>
<td>30</td>
<td>7,9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bed Size</th>
<th>f</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>50 or less</td>
<td>171</td>
<td>45,2</td>
</tr>
<tr>
<td>51 - 200</td>
<td>128</td>
<td>33,9</td>
</tr>
<tr>
<td>200+</td>
<td>79</td>
<td>20,9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>IT Department</th>
<th>f</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Owned</td>
<td>352</td>
<td>93,1</td>
</tr>
<tr>
<td>Not Owned</td>
<td>26</td>
<td>6,9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Outsourcing</th>
<th>f</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yes</td>
<td>26</td>
<td>6,9</td>
</tr>
<tr>
<td>No</td>
<td>352</td>
<td>93,1</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>IT Usage Instruction</th>
<th>f</th>
<th>%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Owned</td>
<td>184</td>
<td>48,7</td>
</tr>
<tr>
<td>Not Owned</td>
<td>194</td>
<td>51,3</td>
</tr>
</tbody>
</table>

| Total               | 378| 100 |

Hypothesis Tests

First research hypothesis examines the effects of individual characteristic of hospital managers on computer use, and the results of stepwise regression analysis testing this hypothesis were shown in Table 5. The goodness-of-fit tests of the model showed that the model is appropriate to test the relationship between dependent and independent variables. The results suggest that only job position of hospital managers was found to be statistically significant socio-demographic characteristic even if this variable explains less than 1 percent of dependent variable. The effects of all other socio-demographic characteristics were found to be insignificant. According to the results, those managers who were holding hospital administrator position that might be financial, logistic, hotel services, etc., had more positive attitude against computer use (β=0,266, p≤0,05) compared to hospital directors that are top managers of hospital and medical directors that are responsible from medical services in their hospitals and mostly physicians.

Table 5. Individual Factors Affecting Attitudes of Hospital Managers Towards Computer Use

<table>
<thead>
<tr>
<th>Sig.</th>
<th>Var.</th>
<th>B</th>
<th>Std. Err.</th>
<th>β</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
</table>

Northeast Decision Sciences Institute 2017 Annual Conference
The second research hypothesis examines the relationship between the attitudes of hospital managers against computer use and the main characteristics of the hospitals where hospital managers worked at. The results of stepwise regression analyses testing for hypothesis were given in Table 6. The variable of hospital status that shows if hospitals were general or specialized hospital was found to be statistically significant organizational factor affecting the attitude of hospital managers against computer use. When compared to those managers who were working at specialized hospitals, those managers who were working general hospitals had more positive attitude against computer use ($\beta=0.669$, $p \leq 0.05$). The results suggest that hospital status might affect significantly the attitudes of hospital managers against computer use. In this model, another significant variable is region of hospital. Managers who work in hospitals in Region 6 (South-Eastern Region) have more positive attitude towards computer use than those in other regions ($\beta=0.386$, $p \leq 0.05$). In addition, variable of satisfaction with HIT outsourcing service is found to be significant in the model ($\beta=0.308$, $p \leq 0.05$).

Table 6. Organizational Factors Affecting Attitudes of Hospital Managers Towards Computer Use

<table>
<thead>
<tr>
<th>Sig. Var.</th>
<th>B</th>
<th>Std. Err.</th>
<th>$\beta$</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\text{Constan}t$</td>
<td>3.070</td>
<td>0.480</td>
<td>6,392</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>$\text{Hospital I Status}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\text{General Hospital}$</td>
<td>2.100</td>
<td>0.387</td>
<td>0.669</td>
<td>5.421</td>
<td>0.000</td>
</tr>
<tr>
<td>$\text{Spec. or Training Hospital}$</td>
<td>Reference</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$\text{Hospital Region}$</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Region 1</td>
<td>0.215</td>
<td>1.732</td>
<td>0.098</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Region 2</td>
<td>0.097</td>
<td>0.682</td>
<td>0.503</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Region 3</td>
<td>0.011</td>
<td>0.082</td>
<td>0.935</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Region 4</td>
<td>0.054</td>
<td>0.429</td>
<td>0.672</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Region 5</td>
<td>Reference</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Region 6</td>
<td>0.490</td>
<td>0.155</td>
<td>0.386</td>
<td>3.154</td>
<td>0.005</td>
</tr>
<tr>
<td>Region 7</td>
<td>0.089</td>
<td>0.609</td>
<td>0.549</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
This research also expected that there was a significant relationship between individual characteristics of hospital managers and their attitudes against internet use (Research Hypothesis 3). The effects of individual characteristics on the attitudes against internet use showed that the years of using computer at home was a significant factor affecting negatively the attitude of internet use of hospital managers ($\beta=-0.252$, $p\leq 0.05$) (Table 7). This result means that, higher the years of computer use at home increases the negative attitude of hospital managers against internet use, thus third research hypothesis was supported by the results.

### Table 7. Individual Factors Affecting Attitudes of Hospital Managers Towards Internet Use

<table>
<thead>
<tr>
<th>Sig. Var.</th>
<th>B</th>
<th>Std. Err.</th>
<th>$\beta$</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cons.</td>
<td>5.245</td>
<td>0.181</td>
<td>28.94</td>
<td>2</td>
<td>0.000</td>
</tr>
<tr>
<td>Years of Use PC (at Home)</td>
<td>-0.038</td>
<td>0.015</td>
<td>-0.252</td>
<td>-2.533</td>
<td>0.013</td>
</tr>
</tbody>
</table>

R:0.251 R2:0.063 Adj. R$^2$:0.053 F:6.415 p:0.013 DW:1.882

According to the results of stepwise regression analyzes provided in Table 8, the only significant organizational characteristic affecting the score of internet use of hospital managers was hospital status. The results suggests that those managers who were working at general hospitals had more positive attitude against internet use compared to those managers who were working at specialized or training hospitals ($\beta=0.498$, $p\leq 0.05$).

### Table 8. Organizational Factors Affecting Attitudes of Hospital Managers Towards Internet Use

<table>
<thead>
<tr>
<th>Sig. Var.</th>
<th>B</th>
<th>Std. Err.</th>
<th>$\beta$</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>3.000</td>
<td>0.730</td>
<td>4.107</td>
<td>0</td>
<td>0.000</td>
</tr>
</tbody>
</table>

**Hospital Status**

<table>
<thead>
<tr>
<th></th>
<th>B</th>
<th>Std. Err.</th>
<th>$\beta$</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
<td>2.094</td>
<td>0.745</td>
<td>0.498</td>
<td>2.811</td>
<td>0.010</td>
</tr>
<tr>
<td>Specialize d/ Train. Hos.</td>
<td>Reference</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

R:0.498 R2:0.248 Adj. R$^2$:0.216 F:7.902 p:0.010 DW:1.891

Research hypothesis 5 expected that individual characteristics of hospital managers had a meaningful effect on their attitudes against HIT. The results of testing this hypothesis indicated that only the variable of age of the respondents had a statistically significant and positive effect on the attitude against HIT (Table 9). This variable itself explains about 5 percent of total variance of the attitude score on HIT. The results simply suggest that increasing age increases the positive attitude of hospital managers against HIT. This result supported research hypothesis 5.
The last research hypothesis (H6) expected that organizational characteristics of hospitals that respondent managers worked at general hospital had a significant effect on their attitudes against HITs. The results shown in Table 10 indicate that the variable of hospital status had a statistically significant and positive effect on the attitude against HITs. According to the findings, the managers of general hospitals had also more positive attitude against overall HIT compared to managers of specialized hospitals. As expected, having a manual on using HITs was had a positive effect on the attitude of managers against HITs, supporting research hypothesis 6.

### Table 9. Individual Factors Affecting Attitudes of Hospital Managers Towards HITs

<table>
<thead>
<tr>
<th>Sig.</th>
<th>B</th>
<th>Std. Err.</th>
<th>β</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>3.877</td>
<td>0.453</td>
<td>8.555</td>
<td>0.000</td>
<td></td>
</tr>
<tr>
<td>Age</td>
<td>0.029</td>
<td>0.012</td>
<td>0.243</td>
<td>2.443</td>
<td>0.016</td>
</tr>
</tbody>
</table>

R:0.243 R2:0.059 Adj.R2:0.049 F:5.970 p:0.016

DW:2.008

### Table 10. Organizational Factors Affecting Attitudes of Hospital Managers Towards HITs

<table>
<thead>
<tr>
<th>Significant Variables</th>
<th>B</th>
<th>Std. Err.</th>
<th>β</th>
<th>t</th>
<th>p</th>
</tr>
</thead>
<tbody>
<tr>
<td>Constant</td>
<td>2.833</td>
<td>1.032</td>
<td>2.745</td>
<td>0.012</td>
<td></td>
</tr>
<tr>
<td>Hospital Status</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>General Hospital</td>
<td>3.496</td>
<td>0.714</td>
<td>0.663</td>
<td>4.897</td>
<td>0.000</td>
</tr>
<tr>
<td>Specialized Hospital</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Training hospital</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>IT Usage Instruction</td>
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DW:1.685

### Results and Discussion

The effects of some individual characteristics of hospital managers and organizational characteristics of hospitals where managers were working at were investigated. The results suggested that managerial position, hospital status, length of years of using computer at home, IT usage instruction of hospital, which is the manager’s work for, hospital region, and age of the managers were having significant effects on the attitudes of managers against the components of HITs.

Compared to hospital and medical directors that were almost all educated in medicine, hospital administrators that were having the managerial responsibility for financial and administrative duties of hospitals had a positive and statistically significant attitude against the main components of HITs. This finding might be explained by the fact that hospital administrators are more involved in computer use in their daily routines and duties compared to other medical-oriented hospital managers. Therefore, spending more time in using computers every day and seeing the positive impacts at their job for years might have a positive effect on the perception about computers. The more computer use the more benefit gain and higher positive attitude against use computers.

Of the individual and organizations variables, only age of respondents had a positive effect on overall HIT attitude score. The results showed that respondents who were relatively older had more positive attitude against HIT compared to relatively younger respondents those who were under 40 years old. This result is consistent with the study of Moghaddam and Abadi [16]. They also found that increasing age affected using advanced technologies in a positive way.
Individual factors like gender, age, and experience have an impact on the link between facilitating conditions and technology use intention [17]. In concert with age and gender, experience can further moderate the relationship between facilitating conditions and behavioral intention. When technology users have not developed their knowledge and skills (when they have less experience), the impacts of age and gender on consumer learning will be more significant than when they have acquired enough knowledge or expertise about the technology (when they have more experience). The dependence on facilitating conditions is of greater importance to older women in the early stages of technology use because, as discussed earlier, they place greater emphasis on reducing the learning effort required in using new technology [15].

Among the organizational characteristics of hospitals where respondent managers were working at, hospital status was found to be having a significant effect on the attitude of managers against ITs. The results indicated that respondent managers of general hospitals had more positive attitude against computer use, internet use, and HIT. When considering the dominant characteristics of specialized and training hospitals in Turkey, it can be said that general hospitals are working in a manner where lack of specialization and cooperation, and professionalism is a case. In addition, since these hospitals are smaller, it can be expected that computing departments and computing personnel be easily accessed when they are needed, and the communication is not complex like in bigger hospitals, which are usually specialized and training hospitals. As a result, difficulty in using technologies and resistance against using technologies, and mirroring the resistance to the managers might be cases in specialized and training hospitals where work variety and lack of specialized personnel in HIT are cases. So all these facts might be reason why managers of general hospitals have a positive attitude against the components of HITs.

Similar study conducted by Burke and her colleagues showed that being a training hospital is an organizational factor that may affect technology diffusion and market competition among hospitals in a region. Teaching status makes necessary the introduction of new technologies. However, resistance against new technologies might be a common problem among the hospitals since health care personnel might have difficulties in adapting every new challenges in their hospital. For this reason, it can be concluded that it is not a surprising finding showing that the managers of specialized and training hospitals have more negative attitude against HIT, which always needs new challenges, and this finding is consistent with the culture of teaching hospitals that invite rather than distrust innovations [18].

Expecting HIT more efficient and effective depends on various factors. Beside individual and organizational characteristics, lack of training to use of HIT and adaptation, and startup cost [19], insufficient information safety and threats, and inadequate standards [20] are all factors that should be thought in advance very carefully before investing in HIT because of features of health care sector [21].

The results of our study showed that those respondents who were working at the hospitals located in the Southeastern region of the country have more positive attitude against computer use compared to other regions of Turkey. Southeastern region is one of the most disadvantageous regions, and the infrastructure of the hospitals in this region is not as good as in other hospitals in other regions. Therefore, not having most advanced computing technologies and HITs in the hospitals in this region might make eager managers of these hospitals to use more computing technologies. There are some studies having similar findings about location of the hospitals and the overall level of technology acceptance. For example, healthcare in the capital can be found to have up-to-date technology and support from healthcare managers. It can also support ease of use of the technology. Different access to technology in the provincial areas of a country has an effect on behavioral intention. In a study, it was found that India and the United States have different technological cultures, including provincial areas, and the culture of the provincial areas affected behavioral intention to use technology [22].

The results of this study also support the findings of other studies showing that there is no single variable or determinant affecting the adoption of ITs and there might be many different variables depending on the organizational culture, country, HIT itself, or the users [23]. However, it is also important to search for the factors having negative effects on adaptation to new HIT and take necessary steps to lessen the negative effects of these factors due to fact that hospital managers who have negative attitude against HIT are not expected to use new technologies effectively and efficiently. HIT play very vital role in increasing health service quality and decreasing medical errors [24], decreasing cost, lowering workload, and increasing time saving [25], increasing patient satisfaction [26], increasing administrative efficiencies, decreasing paperwork, and expanding access to affordable care [19].
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