

22<sup>nd</sup>

# ASIA PACIFIC DSI CONFERENCE

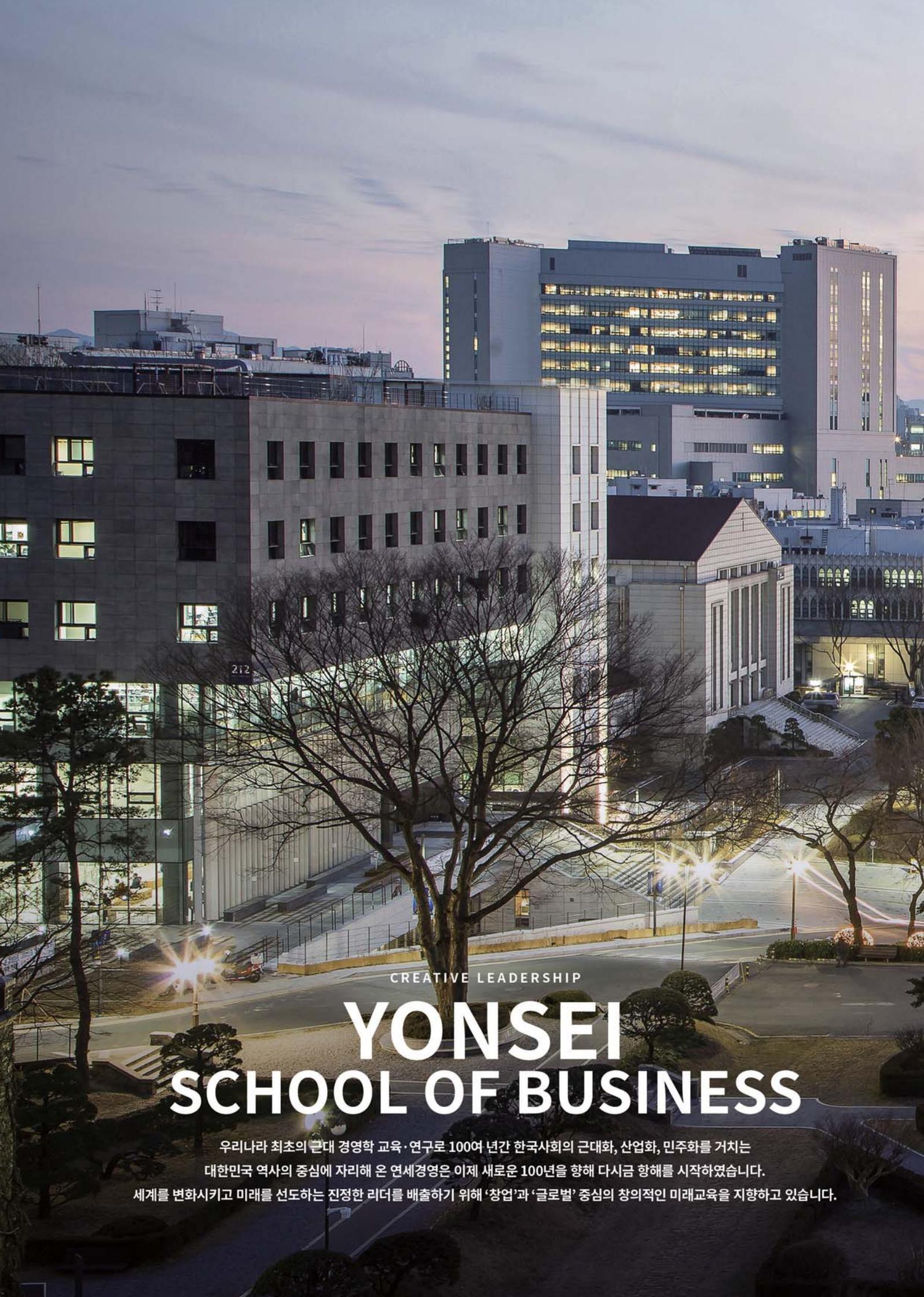
Technology Convergence,  
Innovation & Decision Sciences

PROCEEDINGS

July 21-25, 2017

Yonsei University  
School of Business  
Seoul, Korea





212

CREATIVE LEADERSHIP

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우리나라 최초의 근대 경영학 교육·연구로 100여 년간 한국사회의 근대화, 산업화, 민주화를 거치는  
대한민국 역사의 중심에 자리해 온 연세경영은 이제 새로운 100년을 향해 다시금 항해를 시작하였습니다.  
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**The 22<sup>nd</sup>  
Annual Conference of  
the Asia Pacific  
Decision Sciences Institute**

**“Technology Convergence, Innovation,  
and Decision Sciences”**

**Proceedings**

July 21 – 25, 2017

Seoul, Korea

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# Welcome Message from Co-Conference Chairs

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Greetings!

Welcome to the 22<sup>nd</sup> Annual Conference of the Asia Pacific Decision Sciences Institute (APDSI).

We face unprecedented technological advances, so called, the *Fourth Industrial Revolution* that is characterized by the convergence of various technologies effectively blurring boundaries between the physical, digital, and biological spheres. Ever-increasing speed of innovation and the high velocity of market disruption will create both opportunities and challenges for business enterprises worldwide.

At this critical juncture, the *Korean Production and Operations Management Society* (KOPOMS) and *Yonsei University School of Business* jointly host the 22<sup>nd</sup> annual conference of the Asia Pacific Decision Sciences Institute (APDSI) to provide an exciting and valuable forum where academic scholars and industrial experts can share their knowledge and experience and explore future directions

Keynote speeches and panel discussion on artificial intelligence (AI), internet of things (IoT), smart mobility, and smart cities will offer you significant insights about how such technologies may affect decision sciences and business administration in general.

Moreover, over 100 research papers and abstracts are contributed from 13 countries, 80 of which will be presented in 21 parallel paper sessions during the conference. Innovative and cutting-edge research ideas will be presented and discussed in these sessions. Field tours to Kia Motors Corporation and Samsung Electronics will give you a glimpse of Korean global business powerhouses.

We strongly hope that you will find this conference enjoyable and rewarding, and continue to participate in the future APDSI conferences. Finally, we would like to extend our sincere gratitude to you all for making this conference a success.



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The **Asia-Pacific Decision Sciences Institute (APDSI)** is an interdisciplinary international organization dedicated to the advancement of the science and practice of education and research about business decisions. The Institute promotes excellence in teaching and scholarship, and seeks to serve current and future developmental needs of graduate students, faculty, and industry practitioners. APDSI members come from Australasia, China, Hong Kong, Japan, Korea, Indonesia, Singapore, Thailand, Taiwan, and Vietnam. Since the first conference was held in Hong Kong in 1994, the annual academic conference has been held every July.

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## Korea Production and Operations Management Society (KOPOMS)



The **Korea Production and Operations Management Society (KOPOMS)**, founded in 1988, is the largest organization of academicians in Korea who are interested in production and service operations management. Through academic conferences and publications, the KOPOMS provides a forum for sharing research and promoting collaboration with industry professionals. The KOPOMS has about 800 individual members from 239 universities and 105 firms/institutes in 2016, and hold conferences three times per year.

## Yonsei University School of Business (YSB)



**Yonsei University** was established in 1885, the oldest university in Korea. Now the student body consists of 38,725 students: 26,731 undergraduate students, 11,994 graduate students, 4,518 faculty members, 6,788 staff, and 257,931 alumni. Yonsei operates its main campus in Seoul and has extensive programs in Korean and English. It became the driving force behind Korea's economic and political growth, and it also continues to spearhead university education and research. The opening of an international campus in Songdo, Incheon, in 2010 was the first step for Yonsei University to become a world-class education and research powerhouse. Through decentralization and collaboration among its campuses (Sinchon, Health System, Wonju, International), Yonsei is committed to contributing to the development of mankind and society by leading creative changes and to build a new history.

**Yonsei University School of Business (YSB)** first began to teach commerce in 1915, as the first modern institution of higher education to be established in Korea. In 1950, the College of Business and Economics was inaugurated and followed by the Department of Business Administration in the College in 1958. Subsequently, in March 1965, the Graduate School of Business was launched as the first Korean graduate-level (part-time) business program. To meet the growing needs of an executive education, the Advanced Management Program was launched in 1976. In September 1998, Yonsei took another pioneering step by creating Global MBA program, which was the first full-time English MBA program to be offered in Korea. YSB celebrates its first centennial in 2015 with an ever-stronger commitment to be at the forefront of business education and research. The YSB obtained accreditation in 2008 by the AACSB (Association to Advance Collegiate Schools of Business) International and the KABEA (Korea Association of Business Education Accreditation). In 2012, the School of Business acquired EQUIS accreditation, becoming the first business school in Korea to be accredited by these three accrediting agencies.

**YSB** completed construction of its new home as part of its celebration of its Centennial. The nine-story building encompasses 20,000 square meters of space in six floors above ground and three below. Its design blends both traditional and modern architectural elements and it is the first university building in Korea to receive a certification in Leadership in Energy and Environmental Design (LEED). This building is the conference's main venue.

**The 22<sup>nd</sup>  
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**Full Papers**

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# Best Paper Awards Winners

## Best Analytical Study Paper

### **Designing Hydro Supply Chain for Water, Energy and Food**

*Kwon Gi Mun (Fairleigh Dickinson University), Yao Zhao (Rutgers University), Raza Rafique (Lahore University of Management Sciences)*

### **Portfolio Optimization by Interactive Genetic Algorithm**

*Masato Sasaki (Ashikaga Institute of Technology), Mitsuo Yamashiro (Ashikaga Institute of Technology), Anas Laamrani (Ashikaga Institute of Technology)*

## Best Empirical Study Paper

### **Antecedents and Consequences of Climate Change Conscious Management Practices: An Entrepreneurship Interpretation**

*Su-Yol Lee (Chonnam National University), Ji-Hyun Lee (Chonnam National University)*

### **Exploring Best-Fit Recommendation Mechanisms in Different E-Commerce Scenarios**

*Pei-Fang Hsu (National Tsing Hua University), Pei-Ju Chao (National Tsing Hua University)*

## Best Conference Theme Paper

### **A Study on Innovation Resistance to Home IoT Provided by Telecom Operators**

*Ju Hyeon Kim (Yonsei University), Hyun Jae Park (Yonsei University), Jung Hoon Lee (Yonsei University)*

## Best Student Paper

### **Cultural Ambidexterity is SME's Secret Weapon for Innovation Success? The Effect of Strategic Orientation on Innovation Performance**

*Hyojin Kim (Yonsei University)*

### **Exploring the Implications of Perceptive Relationship-Marketing toward Mobile Self-service Technology of Catering Experience**

*Chiao-Yu Yang (National Pingtung University), Chin-Feng Lin (National Pingtung University)*

# Table of Contents

## Accounting & Finance

<b>Understanding Lehman Brothers Collapse: Towards Preventing Another Lehman</b> .....	1
<i>Thang N. Nguyen</i>	

<b>Portfolio Optimization by Interactive Genetic Algorithm</b> .....	9
<i>Masato Sasaki, Mitsuo Yamashiro, Anas Laamrani</i>	

## Behavioral Operations Management

<b>Job Stressors and Job Performance: Modeling of Moderating Mediation Effects of Stress Mindset</b> .....	26
<i>Hsiao-Ling Chen, Shih-Chieh Fang</i>	

## Big Data & Business Analytics

<b>A Study on the Changes of Online Public Opinion in the Postwar Crisis of Companies Using Opinion Mining</b> .....	35
<i>Jin Hong Park, Jihoon Park, Jung Hoon Lee</i>	

<b>Exploring Best-Fit Recommendation Mechanisms in Different E-Commerce Scenarios</b> .....	50
<i>Pei-Fang Hsu, Pei-Ju Chao</i>	

<b>Analysis of Employment Effects Resulting from Foreign Direct Investment</b> .....	64
<i>Cheng-Chung Wu, Ning Mao</i>	

## Decision Models in Supply Chain Management

<b>Designing Hydro Supply Chain for Water, Energy and Food</b> .....	79
<i>Kwon Gi Mun, Yao Zhao, Raza Rafique</i>	

## Green Supply Chain Management

<b>Drivers for Green Supply Chain Management: Priorities and Impact from Organizational Theory Perspective</b> .....	111
<i>Nisakorn Somsuka, Poomporn Thamsatitdej, Tritos Laosirihongthong, Premaratne Samaranayaked</i>	

<b>Corporate Social Responsibility and Green Chain Management: U.S. Subsidiaries at the Incheon Free Economic Zone</b> .....	123
<i>Wootae Chun, Woojong Sim</i>	

<b>Green Supply Chain Collaboration: A Systematic Literature Review and Citation Network Analysis</b> .....	127
<i>Piyakarn Supanchanaburee, Sakun Boon-itt</i>	

<b>Antecedents and Consequences of Climate Change Conscious Management Practices: An Entrepreneurship Interpretation</b> .....	144
<i>Su-Yol Lee, Ji-Hyun Lee</i>	

## Health Care Management

<b>Social Robotics for Seniors: Customer-build versus Adapted from Existing "Off the Shelf" Technologies</b> .....	159
<i>Jacqueline Blake, Mark Utting, Majid Shishehgar, Don Kerr</i>	

## Innovation & Supply Chain Management

<b>Last Mile Delivery Using Drones</b> .....	166
<i>Shyamsunder Chitta, Ravi Kumar Jain</i>	

Logistics and Transportation Management	
<b>Transportation Network Modeling - The Optimal Route from Single Origin to Single Destination</b> ..176	
<i>Galia Novakova, Kamen Spassov, Yuri Pavlov</i>	
Marketing & Social Media	
<b>Why People Decide to Buy via Social Network Sites</b> .....183	
<i>Chia-Ying Li, Yu-Hui Fang</i>	
<b>Sectioning Social Capital in Virtual World Platforms</b> .....194	
<i>Mohamed Nazir, John Hamilton, Singwhat Tee</i>	
<b>Exploring the Implications of Perceptive Relationship-Marketing toward Mobile Self-service Technology of Catering Experience</b> .....202	
<i>Chin-Feng Lin, Chiao-Yu Yang</i>	
Service Design and Systems	
<b>Post-Contract Outsourcing Relationship Management Capability and Outsourcing Performance: Plant Level Analysis</b> .....215	
<i>Kuo-Chung Chang, Cheng-You Lin, Sessika Siregar</i>	
<b>Exploring Determinants and the Moderating Role of Shopping Orientation of Purchase Intention of Cross-Border Online Shopping</b> .....230	
<i>Eldon Y. Li, Wei-Hsi Hung, Laurence F.K. Chang, Tsai Yen Sheng</i>	
Technology & Innovation Management	
<b>How Openness of Technology and Digital-Resource Readiness Benefit E-service Innovations</b> .....237	
<i>Hung-Tai Tsou, Hsuan-Yu Hsu</i>	
<b>Innovation Resistance Factors and Behavioral Research of Inner Members of Media Companies on the Introduction of ICT-Based Media Technology Innovation: Focused on the MTA Framework</b> .....242	
<i>Gwang Jae Choi, Sungwoo Oh, Jung Hoon Lee</i>	
<b>A Study on Innovation Resistance to Home IoT Provided by Telecom Operators</b> .....253	
<i>Ju Hyeon Kim, Hyun Jae Park, Jung Hoon Lee</i>	
<b>Cultural Ambidexterity is SME's Secret Weapon for Innovation Success?: The Effect of Strategic Orientation on Innovation Performance</b> .....270	
<i>Hyojin Kim</i>	
Alphabetical Authors Index.....289	



# Understanding Lehman Brothers Collapse: Towards Preventing Another Lehman

Thang N. Nguyen (California State University Long Beach)

## ABSTRACT

Lehman Brothers filed for bankruptcy on September 15, 2008. It was resulted from a sequence of critical decisions over time and space. Human decisions in this case, in fact, can be viewed as intertwined *reasoning and emotion* therefore they have not been always rational. We retrace this sequence for the purpose of finding and understanding each major *decision d*, and *its impact measure*  $\mu$  on the institution itself, market and/or economy. We describe the set  $D$  of decisions  $d$  and their impact  $\mu$  as  $\sigma$ -field on  $D$ , namely  $\{D, \mathcal{D}, \mu\}$  where  $\mathcal{D}$  is the power set of  $D$ . With this  $\sigma$ -field on  $D$ , our impact measure  $\mu$ , in terms of, for example, gain or loss, is determined and normalized to be between  $[-1, +1]$ . We look at the behavior of the sequence of  $\mu$  to determine the fate of the institution for intervention towards prevention.

## KEYWORDS

Corporate fiasco; Decision model, Prevention

## INTRODUCTION

Since the first major collapse of Enron in February 2001, there have been congressional hearings (Congressional, 2002), reports (Powers, 2002; Higgs, 2003), and many reforms including Sarbanes-Oxley Act in 2002. The same thing happened after the collapse of Lehman Brothers in September 2008 (Valukas, 2010) with Dodd-Frank Act in 2009, but to a much greater extent, since this one primarily initiated an economic meltdown (Shell, 2015). There have been attempts on how to prevent another Enron (Lagace, 2008) or another Lehman Brothers but they are qualitative, domain specific and/or process-oriented, therefore not comprehensive enough. We revisit the Lehman Brothers' case in this paper with information from numerous sources, notably, Valukas report (Valukas, 2010), "Too Big to Fail" (Sorkin, 2009), "Too Big to Save" (Pozen, 2009), "The Colossal Failure of Common Sense" (McDonald, 2009), research papers for example (Adu-Gyamfi, 2016; Azadinamin, 2012), and multiple sources in news media.

We do not intend to be completely fact exhaustive in revisiting this case. Our idea is to single out and select some relatively highly critical events and outcomes for evaluating the decisions on them and the decision impact to trace its business behavior. The purpose is to develop an understanding while investigating a different approach towards prevention from a decisional and managerial perspective. As we will elaborate next, this is indeed different than most past approaches.

## SUMMARY OF OUR APPROACH TO PREVENTION

The proposed approach involves the investigation of anomalies of corporate business behavior in space time. The assumption is that if anomalies exist, their signs and symptoms are always there. The latter must be completely and effectively monitored.

The anomalies and their signs and symptoms are caused by *human decisions* in space and time. Human decisions, from our perspective, can be viewed as an intertwined *reasoning and emotion* therefore they are not always rational. The evaluation will be described by a measurable *impact* on the institution itself, market and/or economy. Such a measure can be simply financial gain or loss or any equivalent metric.

We describe the set  $D$  of decisions  $d$  and their impact  $\mu$  as  $\sigma$ -field on  $D$ , namely  $\{D, \mathcal{D}, \mu\}$  where  $\mathcal{D}$  is the power set of  $D$ . With this  $\sigma$ -field on  $D$ , our impact measure  $\mu$ , such as gain or loss, is determined and normalized to be between  $[-1, +1]$  by  $f(\mu) = \mu/(1+|\mu|)$ .

We look at the nature and behavior of the sequence of  $\mu$ , to determine the fate of the institution for intervention towards prevention. For example a continuously increasing gain (non-decreasing), continuously decreasing loss (non-increasing) sequence or abrupt and sizable change from positive to negative and vice versa would prompt a review to find its root causes. This might involve interviewing the decision makers. Findings with supporting facts can be represented as line graphs or directed graphs to uncover details of the anomalies potentially leading to corporate fiascos. In time recommended corrective actions can be inserted in the sequence to alter its path for the purpose of prevention.

It can be observed that our approach does not look at choices to be offered by decision methods as in expected utility theory or prospect theory with completely known probability distributions. It is based on a sequence of past decisions already made by responsible parties, with recognizable and measurable impact to the future, and with unknown probability.

## LEHMAN BROTHERS COLLAPSE REVISITED FROM A DECISION PERSPECTIVE

Events, choices and decisions, and outcomes with impact in Lehman's case are obtained from the literature. We capture a couple of important decisions for illustration and discussion purpose.

President Clinton signed into law the Financial Modernization Act or the Gramm-Leach-Bliley Act (GLBA) in 1999, and subsequently the Commodity Futures Modernization Act (CFMA) in 2000. The first repealed the Glass-Steagall Act of 1933. It was to make official prior M&A's of investment banks, commercial banks and insurance for a full range of financial services, such as the case of Citigroup. The second deregulated the financial derivatives trading including over the counter (OTC) credit default swaps (CDS). It included the deregulation of the energy futures trading. This in effect banned the SEC, Fed, CTFC, and others oversight organizations. Early signs and symptoms included the bankruptcy of Orange County, California, Proctor & Gamble lawsuit against Bankers Trust, the failure of Long Term Capital Management (LTCM) (Hera, 2010) and Bear Stearns.

### *Impact*

President Clinton's two rational decisions would have later manifested as dangerous legislation. It has driven (1) Enron to use the loophole in energy futures trading via its illegal special purpose entities (SPE), and (2) Lehman Brothers and others to engage in subprime lending activities and real estate investment with high leverage index, resulting in huge loss and liability when rating become low. After the repeal, banks merged into more complex and high leveraged institutions. It was reported that Brooksley Born predicted troubles if financial derivatives was not regulated (Block, 2009).

President Bush's American Dream Downpayment Act in 2003 was to help low income homeowners with down payment and closing costs. It authorized \$200 million dollars for the program for the fiscal year 2004.

### *Impact*

The Act and its programs generated new hope to low income homeowners. They energized institutions into credit abuse (commercial banks, investment banks, shadow banks, insurance, etc.). This led to NINJA homeowners (no income, no job or asset) with subprime lending. Inability of continuing payments has led to many foreclosures. It was seen early that the American Dream Downpayment Act was a "wasteful and counter-productive extravagance" (Utt, 2003).

Lehman Brothers entered the mortgage loan market and subprime lending to expand their mortgage origination pipeline. It followed a common bank business model: (1) home mortgage loan & mortgage-based securities (MBS), (2) high leverage index, and (3) short-term loans.

### *Impact*

Lehman quickly grew in the subprime market. By 2003 Lehman made \$18.2 billion in loans. It ranked third in lending. A year later, it reached \$40 billion. By 2006, Aurora and BNC, the two lender arms of Lehman Brothers, were lending roughly \$50 billion per month. In the second fiscal quarter of 2007, Lehman reported of \$2.8 billion loss. It eliminated 1,200 jobs. It took a charge of \$25-million after tax. In August 2007, Lehman closed BNC due to mortgage default.

Korea Development Bank (KDB) considered buying Lehman. The sale of Lehman failed as KDB walked away. Lehman Brothers had to use Repo 105 and Repo 108 to boost the bank's financial position. It also used illegal schemes to move transactions and assets off Lehman's books. Lehman's rating was reduced by Moody, S&P and Fitch.

On September 2, 2008, the Fed organized a meeting with bankers of the Wall Street on possible ways to rescue Lehman. US Treasury and the Fed hinted they would not have considered bailing-out Lehman Brothers as they did to Bear Stearns some 6 months earlier. Lehman Brothers was up for sale on September 11, 2008. Lehman was in talks with Bank of America and Barclays. Barclays backed out due to UK regulations. So did Bank of America.

### *Impact*

The Fed-provided reason for not bailing out Lehman Brothers was that Lehman would not have had sufficient collateral to back the loan. The three L's: liability, leverage and loss were high. Lehman Brothers filed for bankruptcy on September 15, 2008

The next day, Barclays bought Lehman Brothers North America. AIG collapsed one day later but was bailed out by the Fed while Merrill Lynch was rescued by Bank of America. Commercial paper market collapsed two days later, The \$500 billion commercial paper market was essentially removed.

## **UNDERSTANDING DECISIONS IN LEHMAN BROTHERS' CASE**

Lehman Brothers filed for bankruptcy on September 15, 2008. Generally speaking, it was resulted from a sequence of critical decisions over time and space (Decisions 1 to 4). We retrace a sequence of decisions as shown for the purpose of understanding each *decision* with focus on *its impact* to the institution itself, business alliances, competitors, consumers, markets and economy. We analyze the decisions made by the responsible authorities within Lehman Brothers, business alliances or competitors, US Treasury, and/or the Fed (state and/or federal).

The set of decisions over space time called out previously is considered highly critical decisions under risk or uncertainty. They have typically driven or moved Lehman Brothers from one state to the next over roughly a decade, from 1997 to 2008.

At closer look, it was reported that Decision 1 was rushed through Congress (Blumental, 2011). Blumental's findings were that it all started with Brooksley Born, Chairperson of Commodity Futures Trade Commission (CFTC). Born wanted to regulate the booming futures market, in particular financial derivatives and CDS (credit default swap). Her attempt was opposed by Fed Chairman Alan Greenspan, US Treasury Robert Rubin and later Larry Summers, and SEC Arthur Lewitt. Meanwhile, Congress, led by Gramm, Lugar and Erwing was working on a bill on deregulation over derivatives (financial and energy derivative trading) and CDS (Hera, 2010).

Among the many questions which could be asked on, for example, in Decision 1, we single out: (1) "Was the bill a plain reaction or response by someone or some group's motivation or desire, according to their own perspective?", (2) "Did the bill follow any economic guiding principles between current thinking, e.g. Keynes or Hayek, and even driven by the old Adam Smith's psychological ad-hoc rules?", (3) "Did the bill ignore any set of overall policy governing the control of financial market?", and (4) "Whether decision science, notably decision under risk and under uncertainty such as expected utility theory of von Neumann and Morgenstern and/or Kahneman and Tversky's prospect theory played any role in the analysis of the decisions?"

The answers to the first three questions are "probably yes". And the answer to the last question is "probably not". The reason is that the basis of decision science assumes a known probability distribution which is not the case for this set of decisions. Furthermore, the decisions by the decision makers in Congress, government and business are mostly, if not all, based on their experience, expertise and feeling. This is what Daniel Kahneman (2011) identified as an intertwined emotion (thinking fast or system I) and reason (thinking slow or system II).

Other decisions, at closer look, would have been influenced by emotion as well, with or without reasoning based on some detailed analysis. While the decisions by KDB and Barclays appeared rational, the decision by the Fed and US Treasury and of Richard Fuld might not.

It was reported that human character of the decisions makers and their emotion (such as Fuld, Paulson, and Greenspan) played an important role in this case (Sorkin, 2009). A decision model addressing this and future cases towards prevention should account for complete signs and symptoms of anomalies and the non-rational aspect of decisions often made on the fly.

**SKETCH OF A DECISION MODEL**

In a quest to preventing another Lehman Brothers, we propose an approach to the decision problem differently, i.e. from an outsider perspective looking into decisions and decision makers. Our proposed conceptual model is sketched as a tetrahedron in Figure 1. Since most of us are not lawmakers or top executives, what we can possibly do from this perspective, as researchers and/or analysts, are (but not limited to): (1) monitoring *signs and symptoms* of fiascos as they occur (indicated by the bottom left vertex in Figure 1), (2) attempting to understand and evaluate their associated *decisions* in space time (the bottom right vertex), and (3) offering in time the findings and recommendations to the responsible parties to the institution leadership (top left vertex) by an oversight organization unit (top right vertex) for possible intervention.

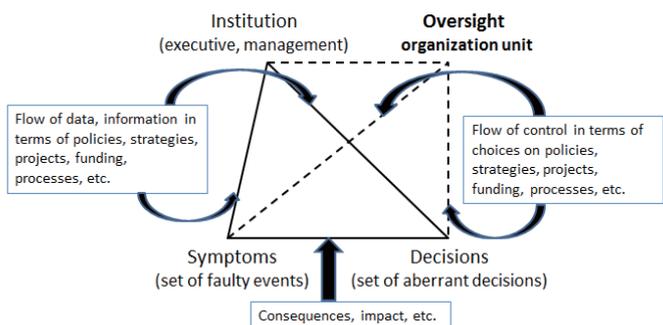


Figure 1: A decision evaluation model

**FIGURE 1 EXPLAINED: THE WHAT, THE HOW AND THE WHO**

*The what: sign and symptoms (bottom vertex of the tetrahedron)*

In any institution, humans can make non-rational decisions leading to critical situations, collectively termed as fiascos. The signs and symptoms of corporate fiascos are always there but they might not be detected or just ignored by the responsible parties for any reason at all. Undesired outcomes might be covered up if non-rational decisions are intentional such as in fraudulent cases.

The situation is analogous to cancer cells in humans (Nguyen, 2016). Cancer cells are always there. They can grow uncontrollably, invading nearby tissue to become a tumor. When the tumor is malignant, its cells have a special protein on their membrane to make them look unharmed to the human body, as friends rather than foes, to escape immunization system. Furthermore, all signs and symptoms on cancer growth are known only to the autonomous nervous system, below the consciousness level. Thus, the growth and proliferation of cancer to other organs are not detected until later stages when they are felt by human consciousness. By that time, it is very much too late for the human body (Alberts et al, 1998; King, 1996). Human dies.

If we think of employees in an institution as analogous to cells in a human body, then abnormal employees can exist, much like cancer cells (Nguyen, 2016). They can grow bad as in the case of Nicholas Leeson of Barings Bank Singapore who used the error account 88888 to hide losses (Rawnsley, 1995) or in Enron case where Andrew Fastow has misused the special-purpose entities in the thousand.

All signs and symptoms of Leeson’s behavior and activities were not known and some were actually down played and ignored by Barings Bank authority (Leeson, 2012) until a reported unaccountable 7.78bn in Japanese yen surfaced. In an attempt to recover the loss and fraud, Leeson exercised a doubling scheme or Martingale (Brown & Steenbeek, 2008) in trading. It failed during the week of Feb 1995. It was too late for Baring Bank. Barings collapsed with £630 in liability and £830 in assets.

The case of Enron was somewhat similar, from a perspective analogous to cancer development. Andrew Fastow of Enron used thousands of special purpose entities (SPE) and influenced Arthur Anderson to keep the losses off Enron balance sheet (Dharan, 2002; Ketz, 2003). The restatement of Q3 2001 led to the restatements of previous years (1997-2000). They exposed severe accounting fraud. Enron collapsed in December 2001.

The lesson learned from this analogy between cancer in human and bankruptcy in institution is that signs and symptoms must be monitored completely and made transparent to all responsible parties. This calls for the making of an information management by exception system (MBE) or a revision of an existing MBE to exercise the intended transparency in monitoring and reporting functionality.

*The how: non-rational decisions (bottom right vertex)*

In this section, we will place the problem in the context of decisions and decision making, the second vertex of the proposed conceptual model in Figure 1. Decision science could offer methods of understanding the decisions listed. But it would be incomplete and incomplete. Impact of decisions is commonly overlooked, therefore incomplete. It is invalid because the previous decision analysis and methods assume a known probability distribution, which is not the case in many decisions cited. There are aspects influencing a decision which are ignored in traditional decision analysis. Underestimation or overestimation frequently occurs. Gut feeling by decision makers overshadows decisions which would otherwise be based on rational choices.

*The who: oversight organization unit (top right vertex)*

Currently in a typical corporate organization, the Board of Directors is the only group which can exercise some control over the institution leadership besides regulating agencies. The sketch in Figure 1 proposes an Oversight Organization Unit. The head of this unit would be appointed by the Board. It is assisted by a group of expert analysts. The latter is similar to members of the technical staff in the old days of MS/OR (Management Science/Operations Research). The difference is that this group acts independently from corporate leadership. It can fully access corporate information as provided by the institution. It can approach any executive for eliciting the W's and H of decisions made by the responsible parties. It analyzes past decisions and provides in time recommendations to the Board and corporate leadership when signs and symptoms become critical and when decisions could lead to potential corporate fiascos.

**DETAILING THE MODEL: UNDERLYING CONCEPTS**

The simple model of Figure 1 is rooted in a couple of important concepts. First, *the biological spectrum of the natural continuum*, which human species (organism) is a component of, is defined as scope. Thus, any human-created problems and potential solutions arrived at by humans should be within this scope (Figure 2).

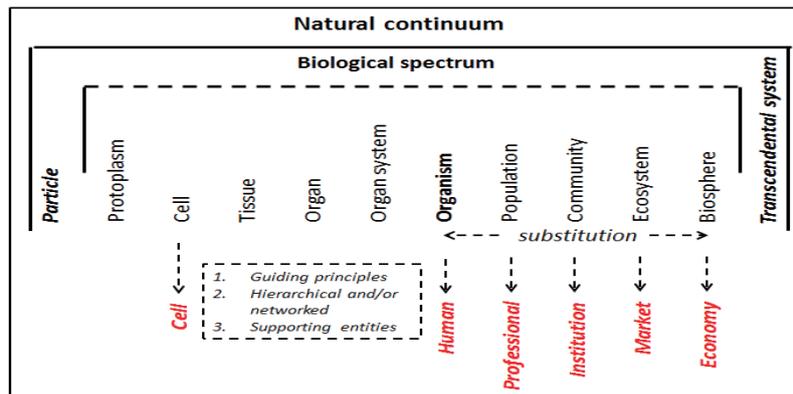


Figure 2: Natural continuum and biological spectrum

Second, some components such as cell are relatively well known (via cell anatomy and cell physiology), with theories, models and practices, while others such as biosphere are less understood. The human mind of the human species has the unique ability of creating abstract products such as the concept of institution (an abstract concept of community), market (an abstract concept of ecology) and economy (an abstract concept of biosphere) or physical entities such as nature- or human-manufactured products of all kinds. The assumption is that all human-created products, abstract or real, must have based on some common roots, i.e. some similar *guiding principles, some natural laws, rules and regulations, or processes*. They are described and used in different disciplines. The similarities among the disciplines were von Bertalanffy's concern in his quest for isomorphism underlying his General System Theory. It implies that we could look into relatively well-known components of the spectrum such as cell, organs and organ systems making up the human body, to essentially explore by *analogy and analogical reasoning between components* (towards defining homeomorphism among them) for a better understanding of other components.

Third, the said human products, if scoped right should be influenced by *laws of nature* such as Newton's laws of gravitation, Coulomb law of electric charge, Faraday law of magnetism, Planck' law of quantum and/or Einstein's relativity theory. We have witnessed the housing market boom in early 2000's due to President Bush's decision to sign into law the American Dream Downpayment Act. Much like a physical force applied to a moving object, this law moved and energized low income home buyers and all sort of lenders, including commercial and shadow banks. We also have witnessed that this boom has generated unprecedented practice on subprime lending and uncontrollable trading on financial derivatives among investment banks and all kinds of investors in time and space. The laws of nature as well as *theory of the mind* such as George Kelly's Personal Construct Theory (Kelly, 1963) can assist in understanding human decisions.

And fourth, since humans have abstracted the world and its behavior in mathematics language, some discipline of mathematics can be used to represent the problems of the world. We know that  $\sigma$ -algebra ( $\sigma$ -field) as a theory of measure, has been used in von Neuman & Morgenstern's expected utility theory for decision models, or Kahneman's prospect theory in economics.

We claim that the above four concepts could be of assistance in our formulation of a decision model for preventing corporate fiascos created by human minds, as detailed further in the following.

*Scoping the problem and solution space (first underlying concept: the natural continuum)*

To address our non-rational decisions on signs and symptoms of potential fiascos, we propose a scope which encompasses the set of decisions over time and space, and their impact to the institution itself, its constituents, its business alliances, competitors, the market it is in, and the economy.

The scope is the natural continuum as shown in Figure 2, ranging from particles to transcendental systems (the unknown). The open dotted lined box on the top of Figure 2 depicts the biological spectrum, where the institution (community), market (ecosystem) and economy (biosphere) are abstract concepts defined by the human mind.

*Analogy and analogy reasoning (second underlying concept) to explore homeomorphisms*

From this systemic perspective, the human body would involve components on the left of the organism component (Figure 2), while the human mind involves those components on the right. The closed dotted box suggests that we should pay attention to the guiding principles, the structural organization, and the operations at each component level (supporting operational entities).

At the cell level, three guiding principles (Figure 3, the bottom box) govern the cell behavior: (1) “milieu interieur” or internal environment which say that all cells are within an interstitial fluid and plasma of the human body according to Claude Bernard (Gross, 1996), (2) cell dynamics under principles of cybernetics (Ashby, 1957) which exercises the control over cells, and (3) cell metabolism to maintain constancy in the human body made up by cells (Cannon, 1963).

By analogy, these three guiding principles can be extended to the higher components (upper boxes within dotted bracket shown in Figure 3). Analogously, for example, humans in an institution live in a data environment analogous to the “milieu interieur” of cells. They are under control of Norbert Wiener’s cybernetics (Wiener, 1948). This is to maintain homeostasis in human (Cannon, 1963) analogous to constancy in cell.

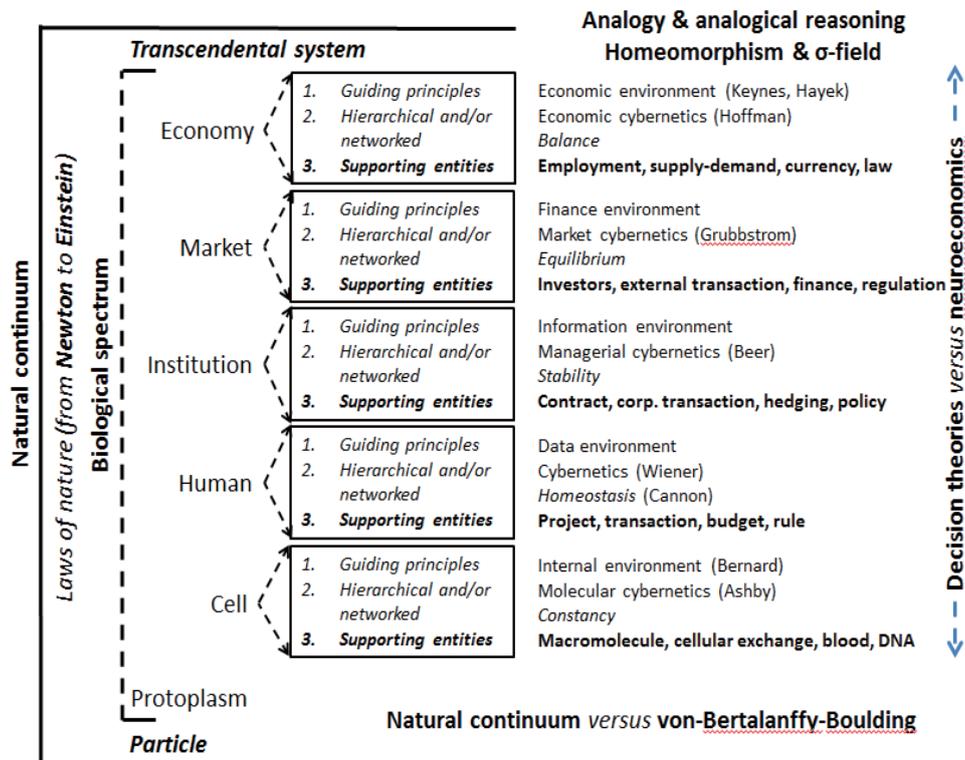


Figure 3: Guiding principles, organization and operations in and across components

Similarly, the institutions are within a sea of information environment, under the control of Stafford Beer’s managerial cybernetics (Beer, 1972). This control was expanded from Wiener’s cybernetics while attempting to maintain institution stability analogous to human homeostasis. The market operates within its environment to maintain market equilibrium, under control of Robert Grubbstrom’s market cybernetics (Grubbstrom, 1969). Finally, the economic environment within it all markets interact is governed by the economic cybernetics (Hoffman, 2010) to maintain economic balance.

We also might equate operational entities in the cell component to employee functionalities in the human component, business functions in institutions, investments in the market and employment in the economy. By the same token, cellular exchange can be considered analogous to transactions between humans, corporate transactions (between institutions), business deals (or external transactions (Coarse, 1937) within markets, or supply-demand in economy. This goes for the analogy between blood (cell level), budget (employee), hedging (institution), finance (market), and capital/credit (economy). DNA (cell level), rules (human level), policy (institution level), regulation (market level) and law (economy level) are also analogous.

Thus, the natural continuum offers a rich analogy between components and their structural, functional and behavioral organizations and operations. This implies that analogical reasoning (or homeomorphism) from one known component can be explored for insights into another. This is different from von Bertalanffy-Boulding’s isomorphism between them, as in General System Theory’s unity of science (Bertalanffy, 1950) and skeleton of science (Boulding, 1956).

*Measuring decision impact (third underlying concept)*

Decision science has been the major underlying tool in quantitative decision making have been used to depict optimum decisions under uncertainty, namely (1) Bentham’s utility function associated values to choices (or decision alternatives) and outcomes (Stigler, 1930), (2) Von Neumann & Morgenstern included the element of uncertainty in their expected utility (EU) theory (von Newman & Morgenstern, 2007), (3) EU over time called discount utility (Matta, Goncalves & Bizarro; 2012), (4) Kahneman & Tversky with their prospect theory (Kahneman & Tversky, 1979) which look at values assigned to gains or losses and decision weights rather than probabilities was an alternative to EU theory, and (5) other tools of MS/OR.

Recently, researchers attempted a new approach to understanding decisions, which is termed as neuroeconomics (Camerer, 2013; Glimcher, Camerer & Poldrack, 2013). Many decisions are emotion-driven as exemplified earlier. This is confirmed by Antonio Damasio in his book “Descartes’s Error (Damasio, 2005). The reason is due to the structure of the human brain. Human has three brains in one, called the triune by Paul MacLean (Newman & Harris, 2009): the reptilian brain (fight or flight), the mammalian brain (emotion) and the neocortex (logical thinking) as performed by the prefrontal neocortex area and the precuneus in the superior parietal area in the brain.

At the neurophysiological level, according to Daeyaol Lee of Kavli foundation (Kavli, 2011), decision making involves multiple brain areas through coordination. To understand the lower level brain disorders and their effects, Lee took a top-down view to explore how prospect theory and reinforcement learning theory related to low-level brain decisions. Lee reviewed various functions used in decision making under risk in economic context, such as utility function for maximizing expected values, value function, discount function and forgetting function for improved inter-temporal choices involving delays of rewards. He examined the shapes of the functions to determine the strength of risk, averse or seeking, in the context of prospect theory.

Consequently, Lee provided an extensive review of decision making and the linkage between neurological level and psychological level, together called *cognitive neuroscience*. Any deviation from normal behavior would lead to different types of neurological and psychiatric disorders. This line of thoughts has discussed in Kable & Glimcher (2009) and research at the Kavli Foundation. The fact is that the above could help explained non-rational decisions.

In 2011, a new line of thought by Kahneman called Think Fast or Think Slow (Kahneman, 2011). It consists of System I which is limbic-driven (think fast) and System II which is neocortex-driven (think slow). It further shows the psychological influence, linking economics to psychology, together called *behavioral economics*. The new trend is to look at neuroscience, psychology, and economics as an integrated neuroeconomics.

From a psychological perspective, there was an existing scheme by George Kelly. Kelly (Kelly, 1963) was the father of Personal Construct Theory (PCT) in clinical environment. He looked at patients with psychological disorders from the basis of dipole concept. A human mind is described as a collection of mental properties on different elements called constructs. The elements are identified from entities such as people, objects, activities, events, etc. Each construct has two extremes: e.g. good versus bad, give versus take, peaceful versus arrogant, friendly versus bullying, etc.

To explore the patient's mind, Kelly's idea was to exercise a carefully designed face-to-face interview with the patient to elicit a set of constructs describing the patient's thoughts and thought process on the elements. The elements are selected as triad (3 elements at a time) for identifying of the similarity between two selected elements (called emergent construct) as opposed to the difference (called implicit construct) between the selected two and the third.

This elicitation would result in a repertory grid (RG) (Bourne & Jenkins, 2005; Fransella & Bannister 1977; Fromm 2004; Stewart & Stewart, 1981; Stewart, 2010). We would apply the PCT and RG into the understanding of symptoms  $S_i$  and decisions  $D_i$  as identified in  $\{Z_i\} = \{S_i \cup D_i\}$  to build the grid. The union indicates either a decision causing symptoms, or a symptoms requiring a decision, or both.

The cells in the grid would be marked with an associated measure, from very similar to very different (Bannister & Mair, 1968; Easterby-Smith, 1980; Korenini, 2012). The technique applied to symptoms and decisions is described in Nguyen (Nguyen, 2014; 2016). At the end of the process, we would obtain a collection of measures  $\mu$ .

#### **Formulating set of decisions D and impact measures as $\sigma$ -field on D (fourth underlying concept)**

We describe the set of decisions D and their impact  $\mu$  as  $\sigma$ -field on D, namely  $\{D, \mathcal{D}, \mu\}$  where  $\mathcal{D}$  is the power set of D. Our  $\sigma$ -field on D is different than but does not exclude the  $\sigma$ -field on events E  $\{E, \mathcal{E}, p\}$  where p is the objective probability measure. The sequence or series of p could be either expressed as Von Neumann and Morgenstern expected utility function for rational choices in decision science, and/or recently as Kahneman and Tversky's prospect value function in economics. Our  $\mu$  is determined by George Kelly's Repertory Grid technique in Personal Construct Theory with consideration on Daniel Kahneman's Thinking Fast and Slow.

We can see decisions leading to bankruptcy can be expressed as the limit of a sequence (or series) of symptoms S and decisions D  
 Sequence  $Z_i = \{D_i \cup S_i\}$  or Series  $Z_i = \sum \{D_i \cup S_i\}$ .

With the numerical measures  $\mu$ , assigned or calculated, associated to the symptom-decision complex, as discussed previously,  $\mu_i$  can be any value and can be either positive, negative or zero, much like gain or loss. To keep  $\mu_i$  within the interval  $[-1, +1]$ , we would use the conversion  $f(\mu_i) = \mu_i / (1 + |\mu_i|)$  to normalize the range of values. We would evaluate the sequence or subsequence of impact  $\{\mu_i\}$  over space and time. If the sequence is non-increasing (continuously increasing or non-decreasing (continuously decreasing), or abruptly changing in direction, it will diverge. If divergent, a subsequence could be injected into the sequence to alter the divergence.

#### *Interpretation of sequence of impact*

The good news is that given a divergent sequence or series one might find and inject a subsequence, which is a controlled one, to the current sequence to force it converge. It implies that the numerical subsequence inserted, when known, can be translated back into a set of decisions to prevent crisis. Of course, it is easy said than done.

As a discrete measure case, we would use the set  $\mu_i = \{-1, -1/2, 0, 1/2, 1\}$  as follows. If the symptom-decision complex value is qualitative (or categorical), its value can be (1) no impact  $\mu_i = 0$ , (2) highly negative impact  $\mu_i = -1$ , (3) negatively impact with  $\mu_i = -1/2$ , (4) highly positive impact  $\mu_i = 1$ , or (5) positively impact  $\mu_i = 1/2$ . Thus, the sequence for consideration on convergence or divergence will be a sequence of values taken from the set of  $\{-1, -1/2, 0, 1/2, 1\}$ . The elements of the sequence can be in any order, therefore the sequence or the series (i.e. sequence and the sum of sequence) can either convert or diverge.

It turns out that we would evaluate the sequence or series of normalized  $\mu_i$  such that if the sequence or series converge, we would reach a local equilibrium. If it diverges, then fiasco will occur. In this case, we can formulate a sub-sequence to insert into the current sequence and bring it to converge.

### **CONCLUDING REMARKS AND FUTURE WORK**

This paper suggest a collections of concepts which could be further developed based on the ideas drawn from biology, physics, psychology, neuroscience, decision science, abstract algebra into business decisions and management. We have only presented the descriptive part of the analogy among various components, physical or abstract of Figure 3.

We need to go deeper via analogical reasoning from known principle, policy and/or process in one matured component for application to another less understood such as market or economy (which are primarily psychologically driven). Since all

components are within the natural continuum, we could further exploit the laws of nature and theory of mind for application. Examples included Norriss Hetherington attempted to see whether Adam Smith was influenced by Isaac Newton (Hetherington, 1983) and Joseph Belbruno discussed the link between John Keynes and Albert Einstein (Belbruno, 2013). With our premise that everything is within the natural continuum where the human body is originated, and the human mind learns from it, the idea is enticing for further investigation and would guarantee the potential solution.

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# Portfolio Optimization by Interactive Genetic Algorithm

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## ABSTRACT

In this paper, we propose a method for supporting investor's judgement based on portfolio optimization using interactive genetic algorithm that present the best compromised solution set that satisfy Pareto optimality and investor's subjective preference structures toward risk and/or return. We develop an interactive system that present investment plan suitable for the investors based on his/her preferences and show an example to apply the system to the real world problem.

## KEYWORDS

Interactive Genetic Algorithm, Portfolio Optimization, Decision Making

## 1. INTRODUCTION

The electronic financial market is fast emerging, the financial products endure substantial transformation with rapid introduction of internet technologies in the financial sector. The financial portals now allow investors to get real time quotes of stock-indices, to track their evolution, to invest in mutual funds. Each of these funds has different characteristics and exhibit a different performance (expected return, risk profile). Investors who decide to invest has to consider a Portfolio optimization based on his/her subjective preferences toward the risk and/or return. However, the number of combination for the investment plans are very huge, it is generally difficult to find the best compromised solution. Genetic Algorithm (GA) is evaluated as an excellent heuristic method for such kind of NP hard problems.

Interactive GA (iGA) is superior to the GA in the point that is able to reflect the decision maker(DM)'s subjective preferences for the real world problems. An iGA is defined as a GA that uses human evaluation. These algorithms belong to a more general category of interactive evolutionary computation. The main application of these techniques includes domains where it is hard or rather impossible to design a computational fitness function, for example, evolving images, music, various artistic designs and forms to fit a user's aesthetic preferences.

In this paper, we propose a method for supporting investor's judgement based on Portfolio optimization using iGA that present the best compromised solution set that satisfy Pareto optimality and investor's subjective preference structures toward risk and/or return such as "risk seeking", "risk averse" and "risk neutral" by applying the interactive phase toward investors. Also, to reduce the investors' burden in this interactive phase, the cluster analysis method is proposed to narrow down the solution space in Pareto frontier which satisfy the investors' preference structure. To apply iGA for portfolio optimization problems, we propose a two-layered chromosome representation. The first layer represents index set that figure candidacy brands of investments. The second layer represents the amount of investment for each brand which satisfy the total budget of investment.

Further, we develop an interactive system that present investment plan suitable for the investors based on his/her preference structure and show the effectiveness of the system by applying the real world investment problem.

## 2. PORTFOLIO PROBLEM

### 2.1 Portfolio Optimization

A portfolio is a grouping of financial assets such as stocks, bonds and cash equivalents, as well as their funds counterparts, including mutual, exchange-traded and closed funds. Portfolios are held directly by investors and/or managed by financial professionals. Prudence suggests that investors should construct an investment portfolio in accordance with risk tolerance and investing objectives.

When determining a proper asset allocation one aims at maximizing the expected return and minimizing the risk. This is an example of a multi-objective optimization problem: more "efficient solutions" are available and the preferred solution must be selected by considering a tradeoff between risk and return. In particular, a portfolio A is dominated by another portfolio A' if A' has a greater expected gain and a lesser risk than A. If no portfolio dominates A, A is a Pareto-optimal portfolio. The set of Pareto-optimal returns and risks is called the Pareto Efficient Frontier for the Markowitz Portfolio selection problem.

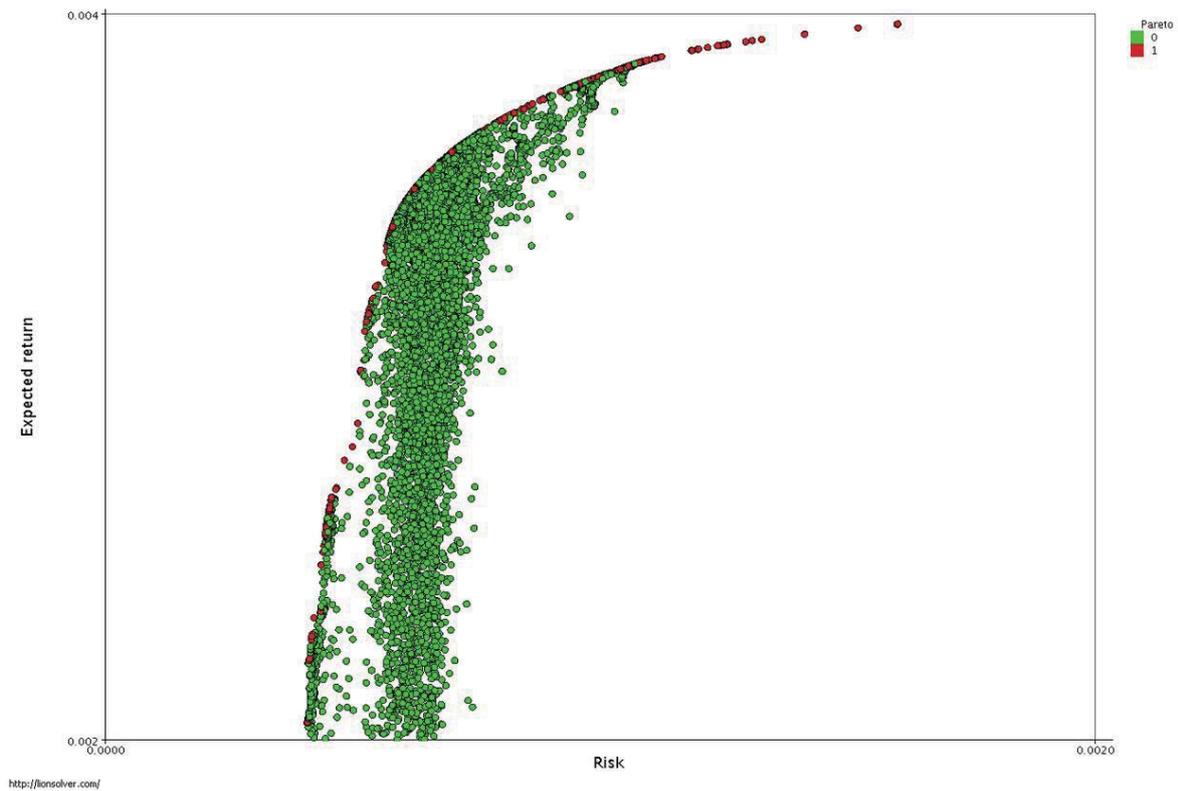


Figure 1: Risk/return plot and Pareto-optimal portfolios (in red)

Recently, an alternative approach to portfolio diversification has been suggested in the literature that is based on maximizing the risk adjusted return.

There are many types of portfolios including the market portfolio and the zero-investment portfolio. A portfolio's asset allocation may be managed utilizing any of the following investment approaches and principles: equal weighting, capitalization-weighting, price-weighting, risk parity, arbitrage pricing theory, the Jensen Index, the Treynor ratio, the sharpe diagonal model, the value at risk model, modern portfolio theory and the capital asset pricing model that we will be discussing next.

## 2.2 Portfolio's risk and return

Modern portfolio theory (MPT), or mean-variance analysis, is a mathematical framework for assembling a portfolio of assets such that the expected return is maximized for a given level of risk, defined as variance. Its key insight is that an asset's risk and return should not be assessed by itself, but by how it contributes to a portfolio's overall risk and return.

MPT assumes that investors are risk averse, meaning that given two portfolios that offer the same expected return, investors will prefer the less risky one. Thus, an investor will take on increased risk only if compensated by higher expected returns. Conversely, an investor who wants higher expected returns must accept more risk. The exact trade-off will be the same for all investors, but different investors will evaluate the trade-off differently based on individual risk aversion characteristics. The implication is that a rational investor will not invest in a portfolio if a second portfolio exists with a more favorable risk-expected return profile – i.e., if for that level of risk an alternative portfolio exists that has better expected returns.

An investor can reduce portfolio risk simply by holding combinations of instruments that are not perfectly positively correlated (correlation coefficient  $-1 \leq \rho_{ij} \leq 1$ ). In other words, investors can reduce their exposure to individual asset risk by holding a diversified portfolio of assets. Diversification may allow for the same portfolio expected return with reduced risk. These ideas have been started with Markowitz and then reinforced by other economists and mathematicians such as Andrew Brennan who have expressed ideas in the limitation of variance through portfolio theory.

If all the asset pairs have correlations of 0—they are perfectly uncorrelated—the portfolio's return variance is the sum over all assets of the square of the fraction held in the asset times the asset's return variance and the portfolio standard deviation is the square root of this sum.

If all the asset pairs have correlations of 1, i.e. they are perfectly positively correlated, then the portfolio's volatility is the sum of each asset's volatility weighted by its fraction held in the portfolio. This is the maximum volatility the portfolio of these assets would reach.

$$E(x) = \left(\frac{E}{S}\right)^{\frac{1}{n}} - 1 \tag{1}$$

With S: present value, E estimated return, and n: the investment period

$$R_p = \sum_{i=1}^n x_i R_i \tag{2}$$

$R_p$ : return of the portfolio

$$E(R_p) = \sum_{i=1}^n x_i E(R_i) \tag{3}$$

$R_i$ : return of investment i

$x_i$ : percentage of investment i in the portfolio

n: number of investment targets

$$V(x) = \frac{1}{n} \sum_{i=1}^n (x_i - \bar{x})^2 \tag{4}$$

$V(x)$ : risk of the investment

### 2.3 Fuzzy portfolio model

Since the solution that will be selected in the portfolio is a Pareto optimal solution on the Pareto frontier, it is reasonable to formulate the portfolio problem as a multi objective problem by maximizing the expected return and minimizing the risk. The fuzzy portfolio model is a model that considers investor satisfaction, and applies the fuzzy concept to the target value for expected return and risk. Investors should set a sufficient level to indicate the required level of satisfaction, the minimum degree of accomplishment, and the degree of achievement to the targeted expected return and risk. This creates membership functions for targeted expected return and risk.

The membership function's expression is obtained by applying the sigmoid function:

$$f(x) = \frac{1}{1 + \exp(-\alpha x)} \tag{5}$$

The fuzzy portfolio model:

$$\begin{aligned} &\text{maximize } \lambda \\ &\text{subject to } \lambda + \exp(\alpha_V(V(x) - V_M)) \lambda \leq 1 \\ &\quad \lambda + \exp(-\alpha_E(E(x) - E_M)) \lambda \leq 1 \\ &\quad \sum_{i=1}^n x_i = 1 \\ &\quad \lambda, x_i \geq 0 \quad (i = 1, 2, \dots, n) \end{aligned} \tag{6}$$

$\lambda$ : Satisfaction level of the solution

$V_M$ : Risk value when satisfaction  $\lambda = 0.5$

$E_M$ : Expected return value for satisfaction  $\lambda = 0.5$

$\alpha_E, \alpha_V$ : Shape parameters of the membership function

### 2.4 Pareto optimization

Pareto optimization is an area of multiple criteria decision making, that is concerned with mathematical optimization problems involving more than one objective function to be optimized simultaneously.

For a nontrivial multi-objective optimization problem, no single solution exists that simultaneously optimizes each objective. In that case, the objective functions are said to be conflicting, and there exists a possibly infinite number of Pareto optimal solutions. A solution is called nondominated, Pareto optimal, Pareto efficient or noninferior, if none of the objective functions can be improved in value without degrading some of the other objective values. Without additional subjective preference information, all Pareto optimal solutions are considered equally good as vectors cannot be ordered completely. The goal may be to find a

representative set of Pareto optimal solutions, and/or quantify the trade-offs in satisfying the different objectives, and/or finding a single solution that satisfies the subjective preferences of a human DM.

A multi-objective optimization problem is an optimization problem that involves multiple objective functions. In mathematical terms, a multi-objective optimization problem can be formulated as:

$$\begin{aligned} & \max(f_1(x), f_2(x), \dots, f_k(x)) \\ & \text{subject to } x \in X, \end{aligned} \tag{7}$$

where the integer  $k \geq 2$  is the number of objectives and the set  $X$  is the feasible set of decision vectors. The feasible set is typically defined by some constraint functions. In addition, the vector-valued objective function is often defined as

$$f : X \rightarrow R^k, f(x) = (f_1(x), \dots, f_k(x))^T \tag{8}$$

An element  $x^* \in X$  is called a feasible solution or a feasible decision. A vector  $z^* := f(x^*) \in R^k$  for a feasible solution  $x^*$  is called an objective vector or an outcome. In multi-objective optimization, there does not typically exist a feasible solution that maximizes all objective functions simultaneously. Therefore, attention is paid to Pareto optimal solutions; that is, solutions that cannot be improved in any of the objectives without degrading at least one of the other objectives. In mathematical terms, a feasible solution  $x^1 \in X$  is said to dominate another solution  $x^2 \in X$ , if:

$$f_i(x^2) \leq f_i(x^1) \text{ and} \tag{9}$$

$$f_j(x^2) < f_j(x^1) \tag{10}$$

For all index  $i \in \{1, 2, \dots, k\}$  and for at least one index  $j \in \{1, 2, \dots, k\}$

As a common concept in multi-objective optimization, we will be using in our proposed solution the weighted sum method, by trying to maximize the sum of three objective functions such as risk satisfaction level, return satisfaction level, budget satisfaction level, and we will propose an evaluation function in the form of:

$$\max(w_1 f_1(x) + w_2 f_2(x) + w_3 f_3(x)) \tag{11}$$

With  $w_1 = w_2 = w_3 = 1$  in our case (review equation 15).

A solution  $x^* \in X$  is called Pareto optimal, if there does not exist another solution that dominates it. The set of Pareto optimal outcomes is often called the Pareto front, Pareto frontier, or Pareto boundary.

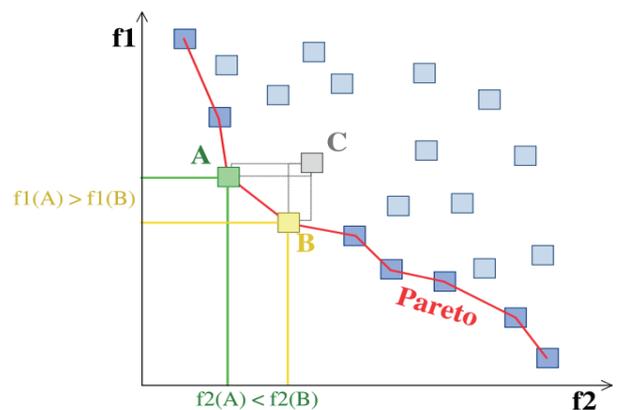


Figure 2: Example of a Pareto frontier (in red)

### 3. CLUSTER ANALYSIS

#### 3.1 Cluster Analysis

Cluster analysis or clustering is the task of grouping a set of objects in such a way that objects in the same group (called a cluster) are more similar to each other than to those in other clusters. It is a main task of exploratory data mining, and a common technique for statistical data analysis, used in many fields, including machine learning, pattern recognition, image analysis, information retrieval, bioinformatics, data compression, and computer graphics.

Cluster analysis itself is not one specific algorithm, but the general task to be solved. It can be achieved by various algorithms that differ significantly in their notion of what constitutes a cluster and how to efficiently find them. Popular notions of clusters include groups with small distances among the cluster members, dense areas of the data space, intervals or particular statistical distributions. Clustering can therefore be formulated as a multi-objective optimization problem. The appropriate clustering algorithm and parameter settings (including values such as the distance function to use, a density threshold or the number of expected clusters) depend on the individual data set and intended use of the results. Cluster analysis as such is not an automatic task, but an iterative process of knowledge discovery or interactive multi-objective optimization that involves trial and failure. It is often necessary to modify data preprocessing and model parameters until the result achieves the desired properties.

The notion of a "cluster" cannot be precisely defined, which is one of the reasons why there are so many clustering algorithms. There is a common denominator: a group of data objects. However, different researchers employ different cluster models, and for each of these cluster models again different algorithms can be given. The notion of a cluster, as found by different algorithms, varies significantly in its properties. Understanding these "cluster models" is key to understanding the differences between the various algorithms. Typical cluster models include:

Connectivity models: for example, hierarchical clustering builds models based on distance connectivity.

Centroid models: for example, the k-means algorithm represents each cluster by a single mean vector.

Distribution models: clusters are modeled using statistical distributions, such as multivariate normal distributions used by the expectation-maximization algorithm.

...

### 3.2 K-means clustering

k-means clustering aims to partition  $n$  observations into  $k$  clusters in which each observation belongs to the cluster with the nearest mean, serving as a prototype of the cluster. This results in a partitioning of the data space into Voronoi cells.

The problem is computationally difficult (NP-hard); however, there are efficient heuristic algorithms that are commonly employed and converge quickly to a local optimum. These are usually similar to the expectation-maximization algorithm for mixtures of Gaussian distributions via an iterative refinement approach employed by both algorithms. Additionally, they both use cluster centers to model the data; however, k-means clustering tends to find clusters of comparable spatial extent, while the expectation-maximization mechanism allows clusters to have different shapes.

Most k-means-type algorithms require the number of clusters -  $k$  - to be specified in advance, which is considered to be one of the biggest drawbacks of these algorithms. Furthermore, the algorithms prefer clusters of approximately similar size, as they will always assign an object to the nearest centroid. This often leads to incorrectly cut borders in between of clusters which is not surprising, as the algorithm optimized cluster centers, not cluster orders.

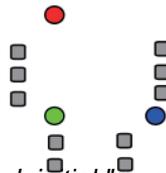


Figure 3: Step1.  $k$  initial "means" (in this case  $k=3$ ) are randomly generated within the data domain (shown in color).

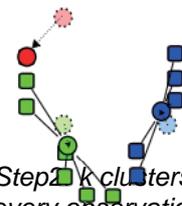


Figure 4: Step2.  $k$  clusters are created by associating every observation with the nearest mean. The partitions here represent the Voronoi diagram generated by the means.

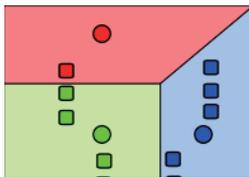


Figure 5: Step3. The centroid of each of the  $k$  clusters becomes the new mean.

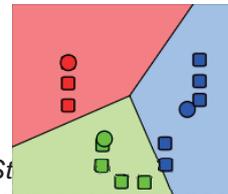


Figure 6: Steps 2 and 3 are repeated until convergence has been reached.

## 4. INTERACTIVE GENETIC ALGORITHM

### 4.1 Genetic algorithm

In computer science and operations research, a GA is a metaheuristic inspired by the process of natural selection. GAs are commonly used to generate high-quality solutions to optimization and search problems by relying on bio-inspired operators such as mutation, crossover and selection.

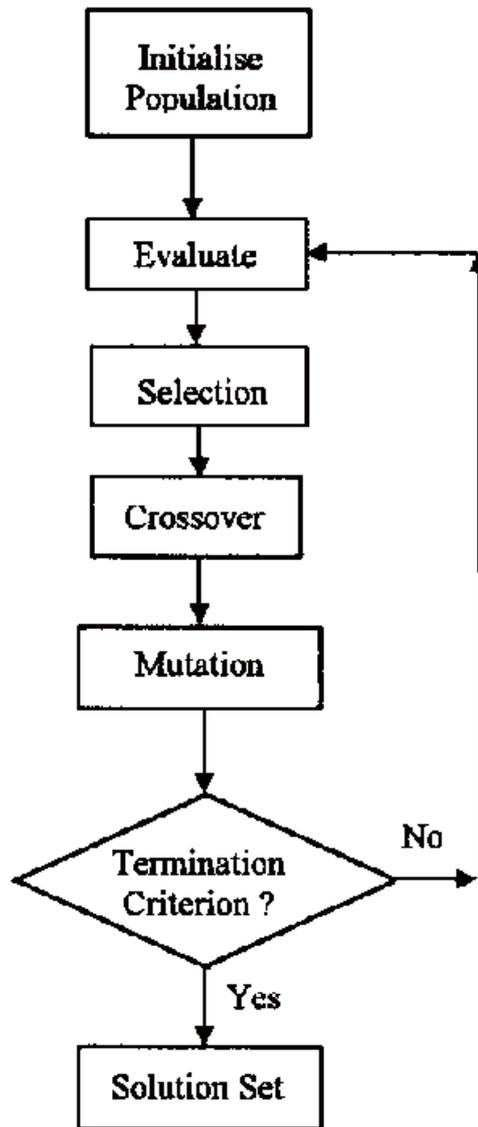


Figure 3: Genetic Algorithm Steps

In a GA, a population of candidate solutions to an optimization problem is evolved toward better solutions. Each candidate solution has a set of properties which can be mutated and altered; traditionally, solutions are represented in binary as strings of 0s and 1s, but other encodings are also possible.

The evolution usually starts from a population of randomly generated individuals, and is an iterative process, with the population in each iteration called a generation. In each generation, the fitness of every individual in the population is evaluated; the fitness is usually the value of the objective function in the optimization problem being solved. The more fit individuals are stochastically selected from the current population, and each individual's genome is modified to form a new generation. The new generation of candidate solutions is then used in the next iteration of the algorithm. Commonly, the algorithm terminates when either a maximum number of generations has been produced, or a satisfactory fitness level has been reached for the population.

The algorithm is divided to the next steps:

**Initialization:** the initial population is generated randomly, allowing the entire range of possible solutions. Occasionally, the solutions may be "seeded" in areas where optimal solutions are likely to be found.

**Selection:** During each successive generation, a portion of the existing population is selected to breed a new generation. Individual solutions are selected through a fitness-based process, where fitter solutions are typically more likely to be selected. Certain selection methods rate the fitness of each solution and preferentially select the best solutions. Other methods rate only a random sample of the population, as the former process may be very time-consuming.

**Genetic operators:** The next step is to generate a second-generation population of solutions from those selected through a combination of genetic operators: crossover, and mutation. For each new solution to be produced, a pair of "parent" solutions is

selected for breeding from the pool selected previously. By producing a "child" solution using the above methods of crossover and mutation, a new solution is created which typically shares many of the characteristics of its "parents". New parents are selected for each new child, and the process continues until a new population of solutions of appropriate size is generated. Although reproduction methods that are based on the use of two parents are more "biology inspired", some research suggests that more than two "parents" generate higher quality chromosomes.

**Termination:**

- This generational process is repeated until a termination condition has been reached. Common terminating conditions are:
- A solution is found that satisfies minimum criteria
- Fixed number of generations reached
- Allocated budget reached
- The highest-ranking solution's fitness is reaching or has reached a plateau such that successive iterations no longer produce better results
- Manual inspection
- Combinations of the above

**4.2 Interactive genetic algorithm**

Interactive Genetic Algorithm (iGA) is a general term for methods of GA that use human evaluation. Usually human evaluation is necessary when the form of fitness function is not known or the result of optimization should fit a particular user preference .

*Table 1: comparison between iGA and GA*

<i>system</i>	<i>sequences</i>	<i>innovator</i>	<i>selector</i>
<i>interactive genetic algorithm</i>	data	computer	human
<i>genetic algorithm</i>	data	computer	computer

An iGA is defined as a GA that uses human evaluation. These algorithms belong to a more general category of Interactive evolutionary computation. The main application of these techniques includes domains where it is hard or impossible to design a computational fitness function, for example, evolving images, music, various artistic designs and forms to fit a user's aesthetic preferences. Interactive computation methods can use different representations, both linear and tree-like ones.

The number of evaluations that iGA can receive from one human user is limited by user fatigue which was reported by many researchers as a major problem. In addition, human evaluations are slow and expensive as compared to fitness function computation. Hence, one-user iGA methods should be designed to converge using a small number of evaluations, which necessarily implies very small populations. Several methods were proposed by researchers to speed up convergence, like interactive constrain evolutionary search or fitting user preferences using a convex function. iGA human-computer interfaces should be carefully designed in order to reduce user fatigue. There is also evidence that the addition of computational agents can successfully counteract user fatigue.

However, iGA implementations that can concurrently accept evaluations from many users overcome the limitations described above.

**5. PROPOSED METHOD**

In the proposed solution of this paper, we apply iGA, that introduces a fuzzy satisfaction level in the evaluation function of the portfolio problem, and selects the optimal portfolio, that satisfies all the satisfaction levels of multiple investors who have more than one objective function, it is a solution that proposes the most satisfying investment plan for the investors.

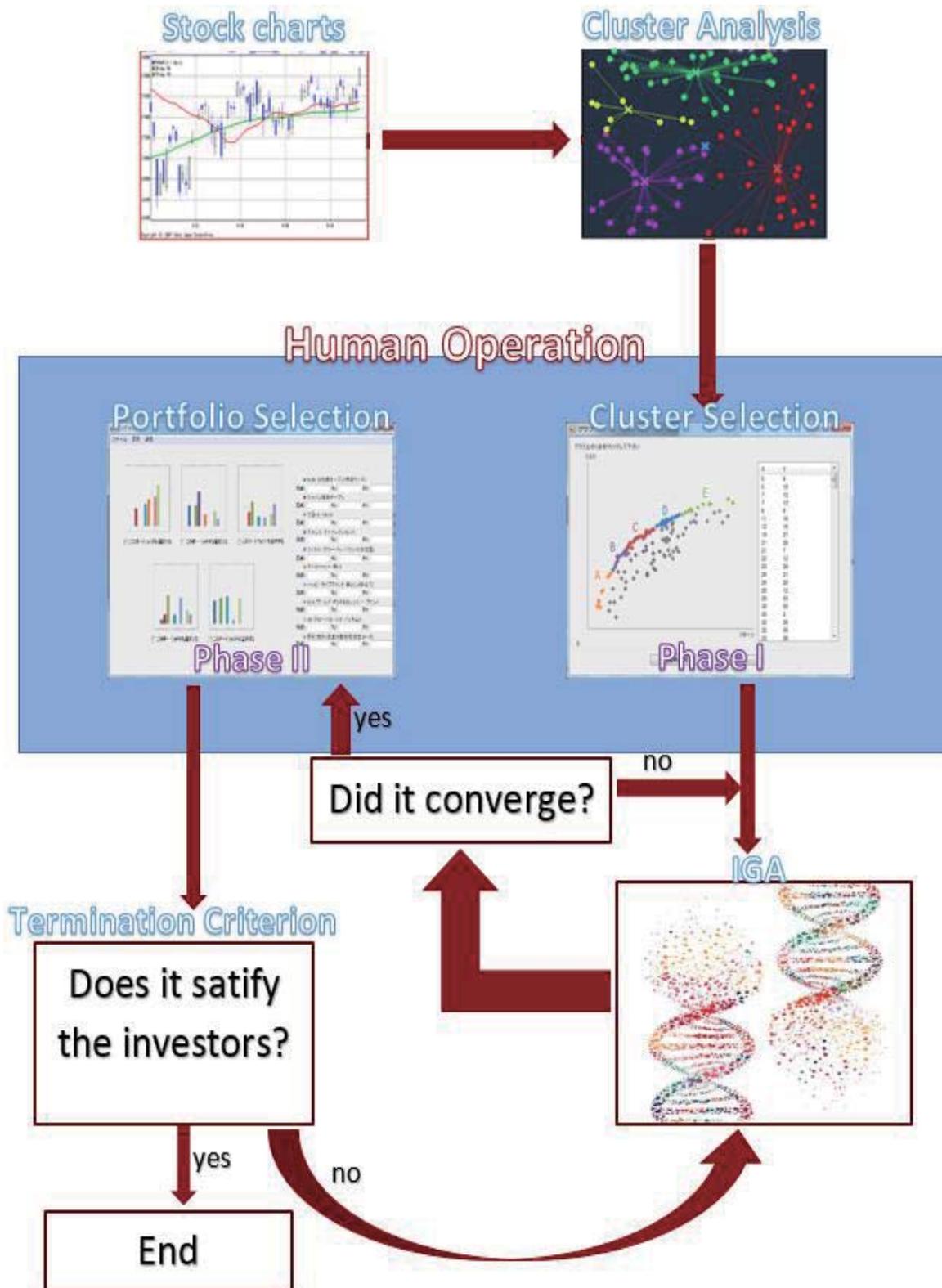


Figure 4: The diagram of the proposed solution

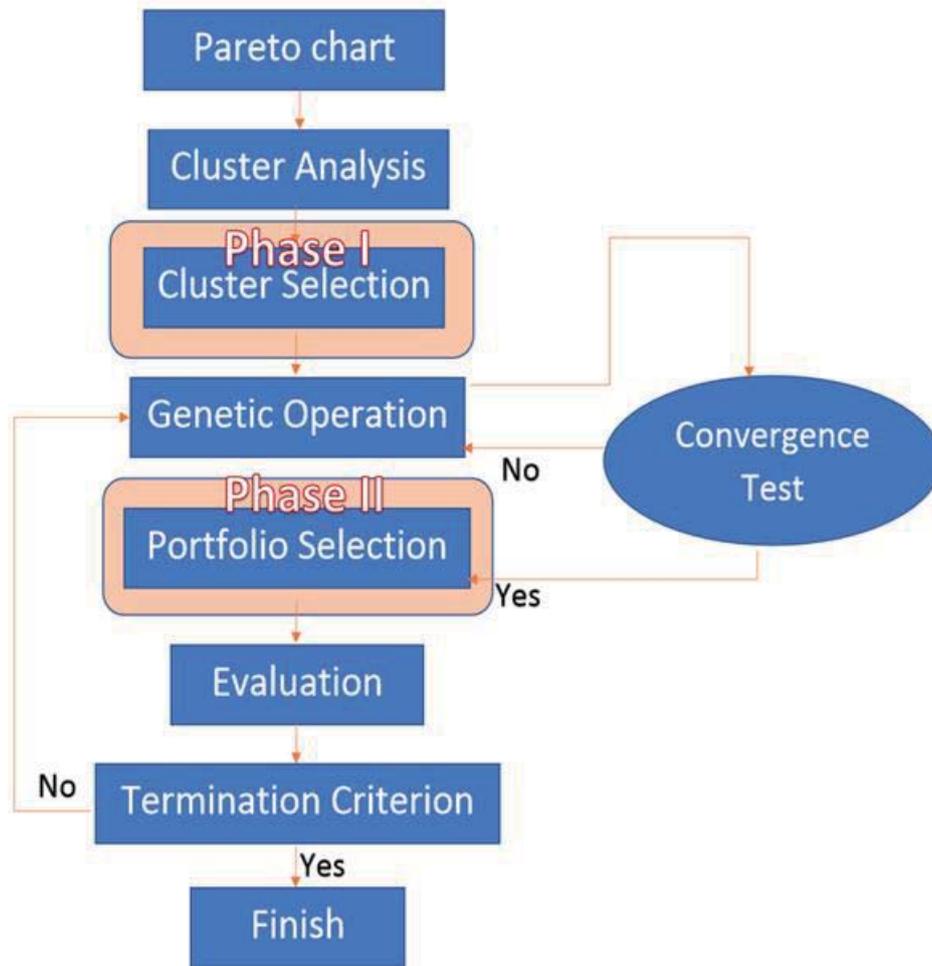


Figure 5: Flow chart of the proposed solution

The steps of the proposed solution for the portfolio problem are shown below:

**Step 1:** Create a Pareto chart

Import actual investment target data, and calculate the risk and return values, then create a scatter plot using the risk as x axis and the return as y axis, then we will have a Pareto chart.

**Step 2:** Cluster Analysis

Investment targets on the scatter plot will be subjected to cluster analysis by the k-means method and will be grouped into five clusters.

**Step 3:** Cluster Selection

Three investment groups from five investment target groups will be selected by the investors based on priorities (phase I).

**Step 4:** Genetic Operation

The investment plan is acquired based on the priority of the cluster determined in step 3, a portfolio chromosome is generated using investment targets of the selected three clusters, and genetic manipulation by GA is performed.

**Step 5:** Convergence Test

When the evaluation value does not change from a certain value or more, it means that it's converging, then we proceed to the selection operation.

**Step 6:** Portfolio Selection

We present 5 portfolio chromosomes generated in Step 4 to the user, so he can select two of them (phase II).

**Step 7:** Evaluation

Evaluate the portfolio with the sum of three fuzzy satisfaction levels.

**Step 8:** Termination Criterion

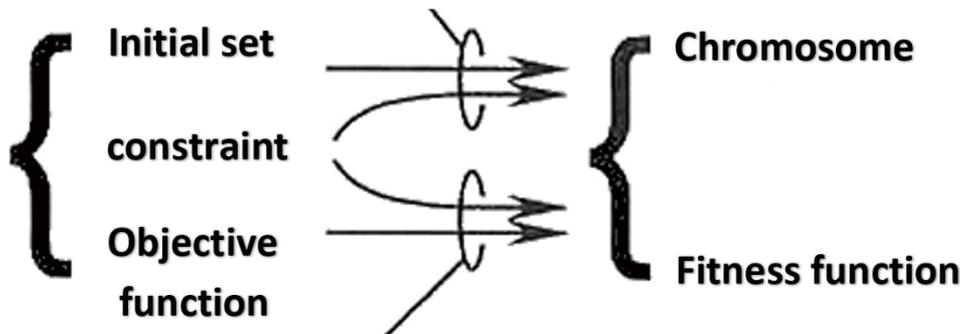
When a portfolio satisfies the investors, the process end, and a final investment plan is presented. If the level of satisfaction is not enough, we return to step 4 and the process repeats.

**Model of the problem**

To optimize the portfolio problem by applying iGA, we first build a model of the problem. In general, the optimization problem is defined by three things, the initial set of candidate solutions, constraint and objective function. On the other hand, the basic components of iGA are chromosome and evaluation function. When building a model of the portfolio problem for iGA, the candidate solution (phenotype) is associated with the chromosome (genotype) and the objective function is associated with the evaluation function, but the constraint is incorporated in the chromosome, or by adding it as a penalty function to the evaluation function.

In the proposed solution, the objective function is determined as maximization of fuzzy satisfaction (fuzzy decision), and the constraint condition will be selected from the Pareto solution by Pareto ranking.

( 1 ) Genetic representation/crossover design



( 2 ) Fitness function design    3 ) Implementation parameters

Figure 6: Design concept of iGA for the optimization problem

**Chromosome representation and genetic operations**

In iGA of the proposed solution, when expressing the portfolio as a gene, we propose a two-layered chromosome representation as shown in Figure 11. First, the information shows what kind of stocks, the investment target located at each locus represents, the index information is added to the stock each time we read the investment target data, and the chromosome is configured by referring to the index (Figure 12).

In order to eliminate the difference due to the position of the chromosome, values are determined from random positions rather than in order, and when the values of the chromosome are duplicated (referring to the same index information), a mutation operation is performed. In the second layer, the investment amount for each investment target that constitutes the portfolio is used as the value of the chromosome, adjusted by satisfaction so that the total chromosome value falls within the investor's funds. Chromosome's value means the investors will have to invest 10,000 dollars for every 1 step, the gene value shows the investment amount and is between 0 and K, and the second and subsequent gene values are determined from K.

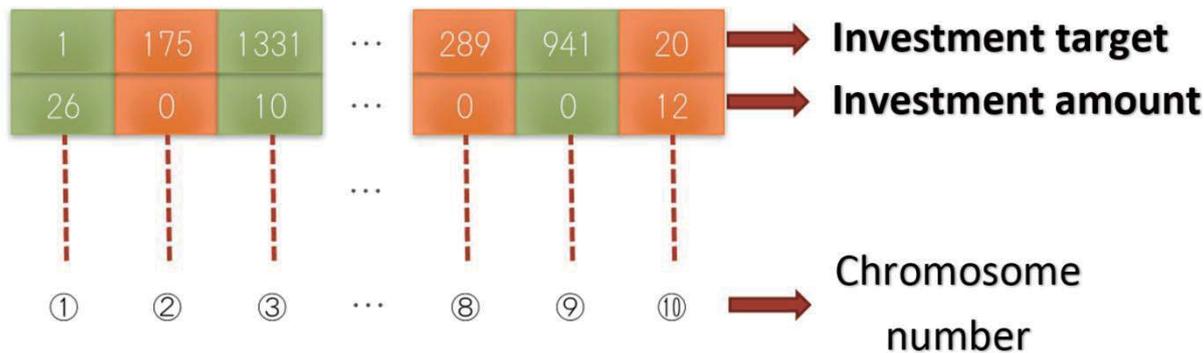


Figure 7: Two layered chromosome representation

Below are the steps showing how to determine the values of the second layer of the chromosome using the investment amount as an allele.

**Step 1:** Set budget K

Investors set the budget they possess K.

**Step 2:** Determining the value of the allele

Pick up a random value (allele) of the second layer of one of the chromosomes showing the investment, the allele will take a value from 0 to K, with K being the maximum value determined in Step 1. In order to eliminate the difference due to the position of information, the position will be determined randomly.

**Step 3:** Repeat the process

The position of the locus is randomly determined, and the allele is randomly determined taking the value:  $0 \sim (K - \sum_{i=1}^n K_i)$

**Step 4:** Terminal criterion

When  $K = 0$  or the number of genes is 10, chromosomes have been generated. Otherwise go back to step 3.

Index	Brand	Cluster
1301	KYOKUYO Co., Ltd	A
1305	Daiwa ETF-TOPIX	B
1306	TOPIX Exchange Traded Fund	A
1308	Listed Index Fund TOPIX	C
1309	SSE50 Index Linked Exchange Traded Fund	A
1310	Daiwa ETF TOPIX Core30	B
1311	TOPIX Core 30 Exchange Traded	A
1312	Russell/Nomura Small Cap Core Index Linked ETF	C
1313	SAMSUNG KODEX200 SECURITIES EXCHANGE ...	E
1314	Listed Index Fund S&P Japan Emerging Equity 100	D
1316	Listed Index Fund TOPIX100 Japan Large Cap Equity	A
1317	Listed Index Fund TOPIX Mid400 Japan Mid Cap Equity	A
1318	Listed Index Fund TOPIX Small Japan Small Cap Equity	C
1319	Nikkei 300 Stock Index Listed Fund	A
1320	Daiwa ETF-Nikkei 225	B
1321	Nikkei 225 Exchange Traded Fund	C
1322	Listed Index Fund China A Share (Panda) CSI300	E
1323	NEXT FUNDS FTSE/JSE Africa Top40 Linked Exchange ...	B
1324	NEXT FUNDS Russia RTS Linked Exchange Traded Fund	A

Figure 8: Correspondence table of stock's index and affiliated cluster

Table 2: Investor's attitude towards risk classification

Risk Averse type	Weak risk Averse type	Risk Neutral type	Weak risk Seeking type	Risk Seeking type
A	B	C	D	E

**Evaluations of the investors**

Evaluation of investor's preference is obtained by the sum of fuzzy satisfaction of risk, return, and budget. Each satisfaction level changes the shape of the membership function according to the value of  $\alpha$  (Figure 13).  $\alpha$  indicates the attitude of investors toward risk.

Portfolio satisfaction is the sum of all satisfactions, and maximization of this satisfaction is the final objective of the solution.

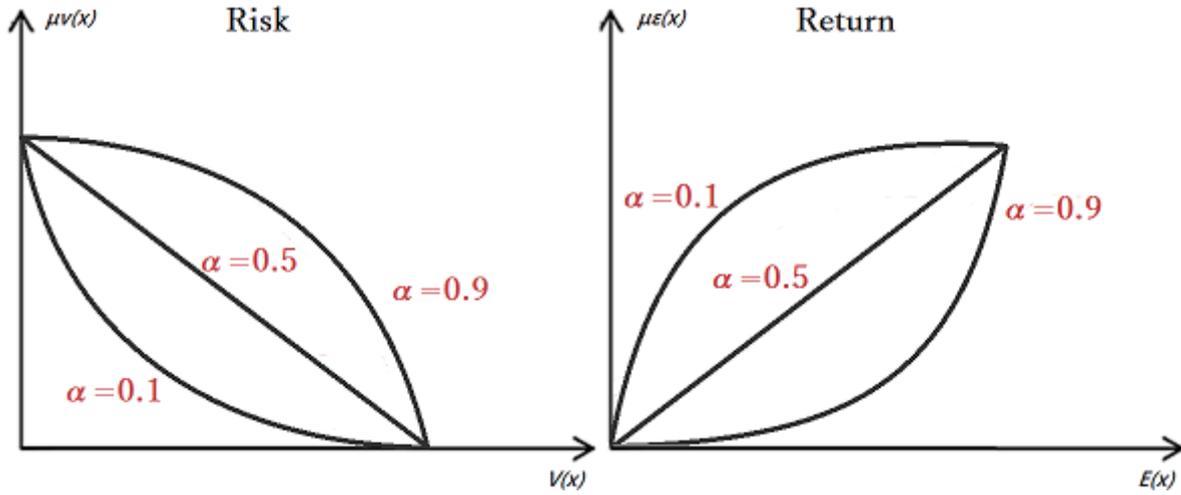


Figure 9: An example of the shape of a membership function in relation with  $\alpha$

An investor always has satisfaction levels for expected return and risk. In the real world of financial management, expert's knowledge and experience are very important in decision-making. Based on experts' knowledge, the investor may decide his/her satisfaction levels for expected portfolio return and risk. Watada et al. (1998) employed a logistic function, i.e., a non-linear S shape membership function to express satisfaction levels of an investor's expected return rate and risk. The S shape membership function is shown in the figure above.

$\mu(V(x))$ : Risk satisfaction level

$\alpha$ : Investors' attitude to risk,

$V_M$ : Risk value at where the level of membership to target risk is 0.5

$$\mu(V(x)) = \frac{1}{1 + \exp(\alpha(V(x) - V_M))} \quad (12)$$

$\mu(E(x))$ : Return Satisfaction level

$\alpha$ : Investors' attitude to risk,

$E_M$ : Expected return value where the level of membership to target expected return is 0.5

$$\mu(E(x)) = \frac{1}{1 + \exp(-\alpha(E(x) - E_M))} \quad (13)$$

$\mu(x)$ : Budget satisfaction level

$K$ : Budget value at which the membership level is 1.0,  $b$ : real number

$$\mu(x) = e^{-b(x-K)^2}, b \geq 1 \quad (14)$$

Portfolio satisfaction level:

$$\mu(V(x)) + \mu(E(x)) + \mu(x) \rightarrow \max \quad (15)$$

### Interface toward investors

The selection that is operated by the investor, has 2 phases. Phase I is a cluster selection interface that selects investors' attitudes toward risks (Figure 14). Since only the investment targets that exist in the Pareto frontier are portfolio components, investment subjects that are inferior are grayed out and displayed. Investors select three priorities from among five color-coded clusters. Investigate the rough investor's attitude to risk here by the selected cluster. Also, based on the priority determined at the time of selecting this cluster, we decide the extraction ratio of investment plan from each cluster which constitute the phase II portfolio (Table 3).

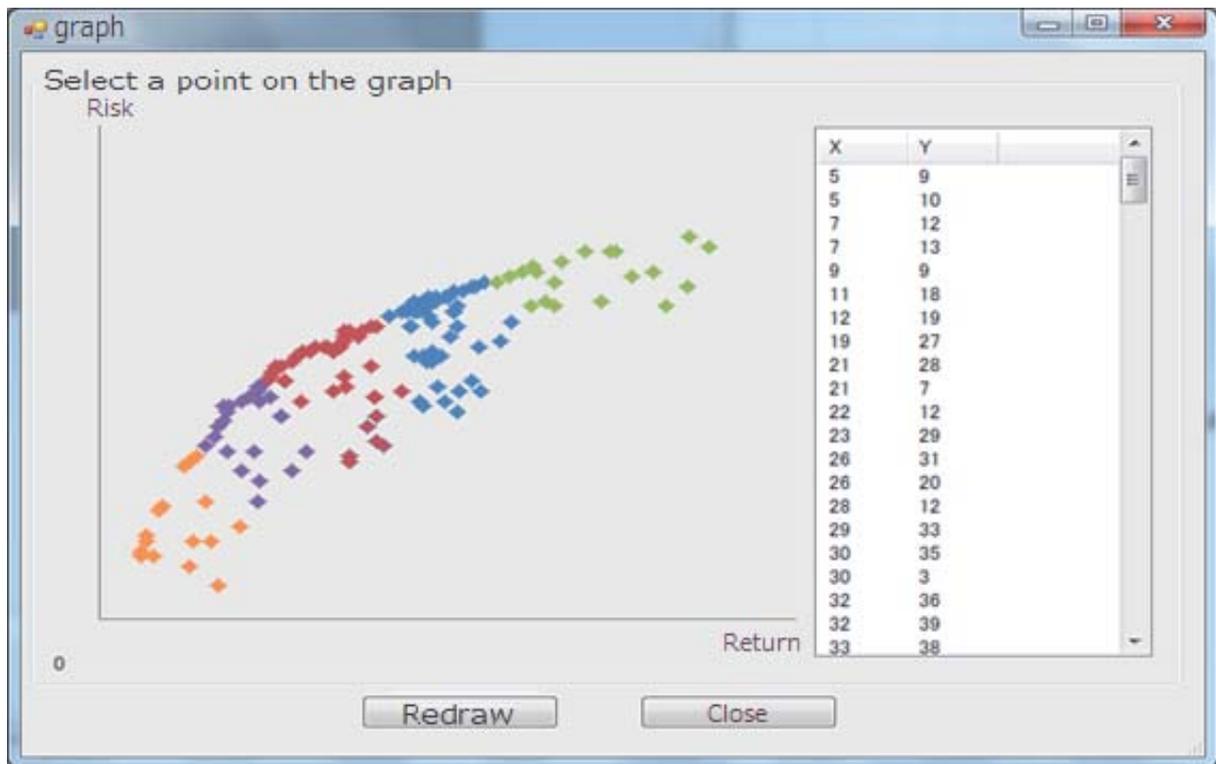


Figure 10: Interface of the Cluster selection (Phase I)

Table 3: Cluster selection ratio

	First cluster	Second cluster	Third cluster
Extraction ratio	6	3	1

Phase II is the portfolio selection (Figure 15). Based on the ratio of the priority determined in Phase I, by extracting 10 investment targets from 3 selected clusters, and referring to the cluster belonging from the index shown in Figure 12, 10 portfolios will be constructed.

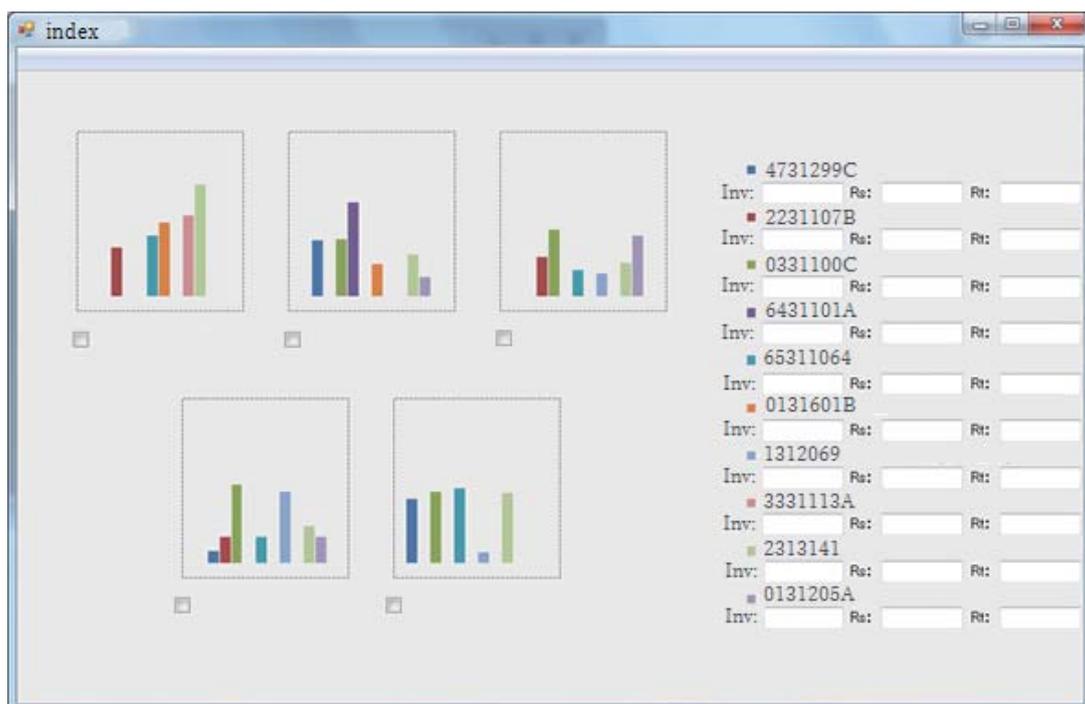


Figure 11: Interface of the Portfolio selection (Phase II)

## 6. APPLICATION

### 6.1 Environments

We will demonstrate a case where the solution constitutes the optimal portfolio for investors. The return and risk values are used as actual data from a deal with Morningstar. Assuming investor's attitude is risk averse type or risk seeking type, we made two rounds of total processing. Below we will describe the investment targets that are selected for the portfolio final plan. In both cases, the investor's budget is set to 10,000 dollars.

### 6.2 Results

The results of constructing the best portfolio in the case where the attitudes of investors toward risks are assumed to be risk averse type or risk seeking type, will be illustrated below. Risk-averse selected clusters are set to A, B, and D in descending order of priority, and risk seeking type clusters are set to E, D, B in descending order of priority. With the assumption that investors are risk averse type or risk seeking type, we will show the application of the proposed solution to the portfolio problem, the selection of the best portfolio, and the GUI created in this research along with the results.

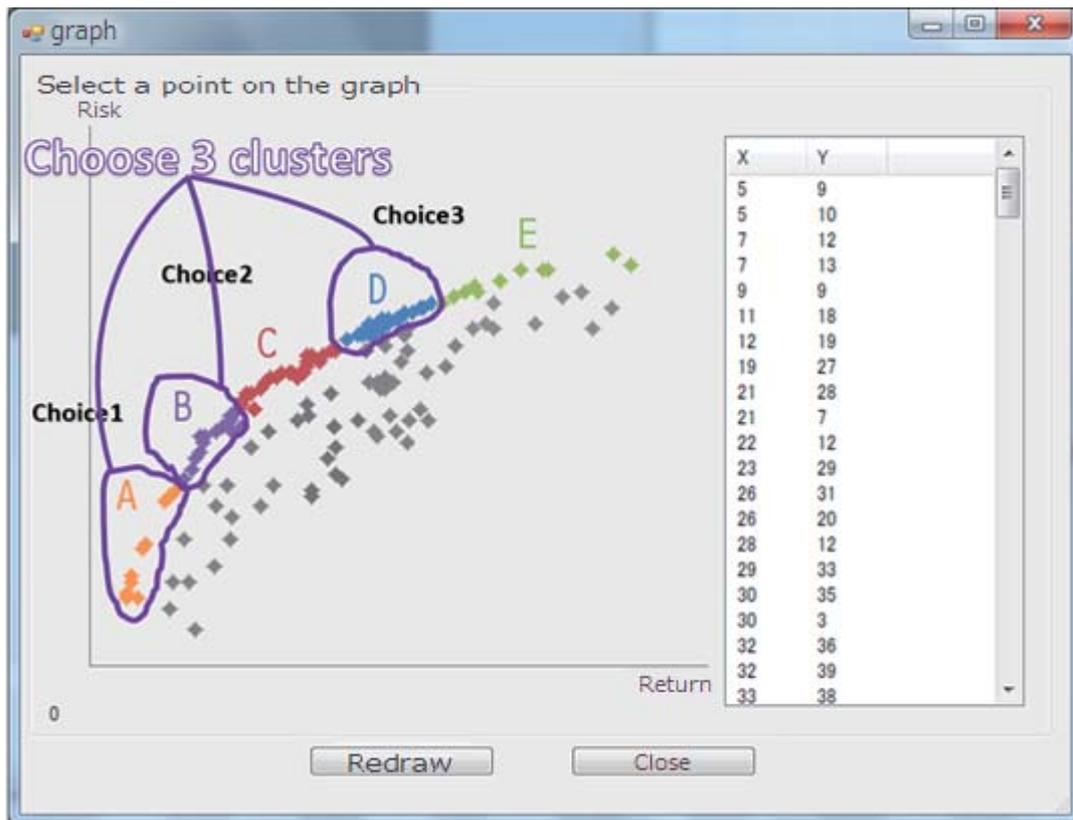


Figure 12: Selection of clusters for risk-averse investors

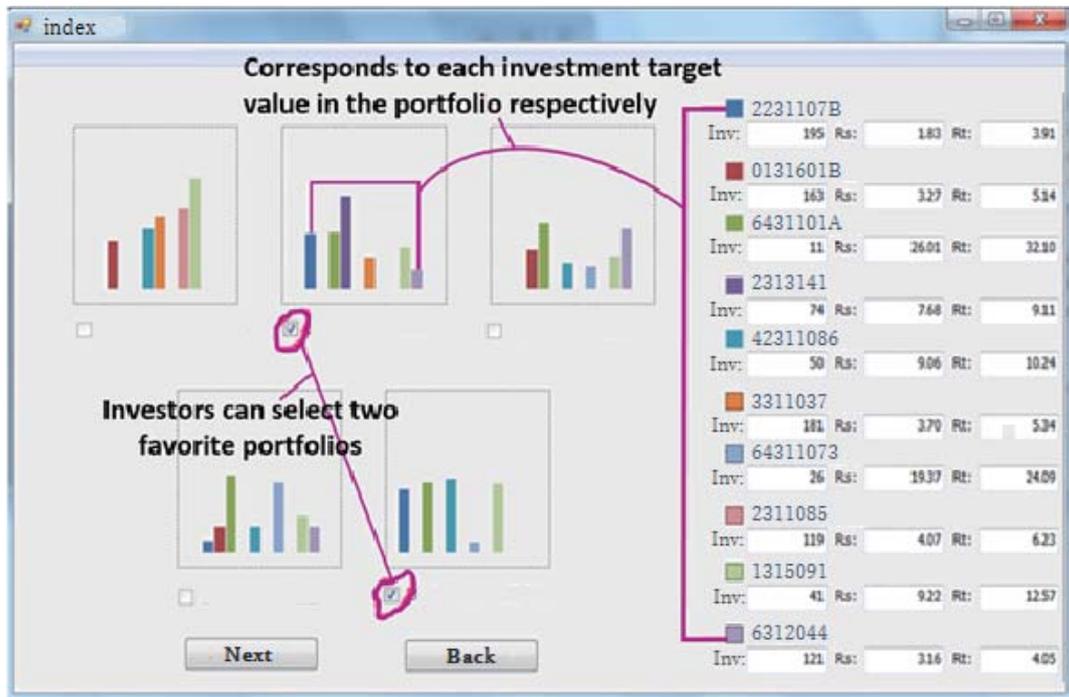


Figure 13: Selection of portfolio for risk averse-type investor

Table 4: Risk averse-type Portfolio

Index	11	90	205	818	620	300	502	43	27	433
Investment amount (in 10,000)	195	163	11	74	50	181	26	119	41	121
Cluster	A	A	D	B	B	A	D	A	B	A

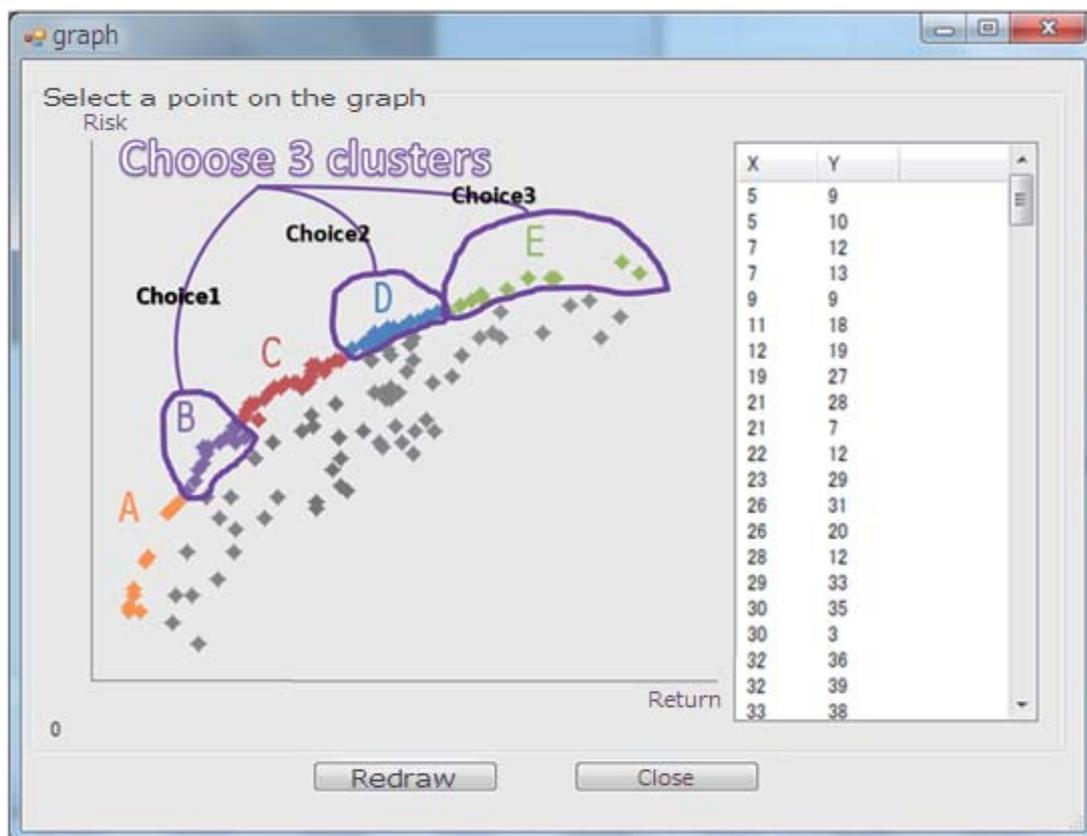


Figure 14: Selection of clusters for risk-seeking investors

Table 5: Risk-seeking type Portfolio

Index	219	304	18	729	401	621	179	910	40	155
Investment amount (in 10,000)	169	409	76	383	85	140	262	44	102	214
Cluster	D	E	D	E	B	E	E	B	D	E

### 6.3 Discussions

The shape of the membership function expressing the risk satisfaction level of risk-averse type investors takes the shape of  $\alpha = 0.1$ , and is shown in the left part of Figure. 13, and the shape of the membership function representing the return satisfaction level has a shape of  $\alpha = 0.9$  shown in the right part of Figure 13, while the risk seeking type each takes the opposite shape.

This result shows that each investor's subjective preference toward risk is reflected in the membership function, and all the investor's risk, return, and budget satisfaction level of the portfolio are fully satisfied by the proposed solution that we have. It also shows risk-averse investors are diversifying investments to avoid risk.

In addition, because risk-averse investors are likely to have a tendency to invest in diversified portfolio to avoid risks, if the cluster selection ratio shown in table 3 is determined in a balanced manner, it is expected that results close to preferences of existing risk-averse investors will be obtained.

And since risk-seeking type investors are likely to have a strong tendency to concentrate and invest in order to obtain returns regardless of the size of the risk, the cluster selection ratio is biased toward one with high priority once determined, we expect to have a portfolio of preferences that closely resembles existing risk-seeking investors.

### CONCLUSIONS

In this paper, we proposed a method for supporting investor's judgement based on Portfolio optimization using iGA that present the best compromised solution set that satisfy Pareto optimality and investor's subjective preference structures toward risk and/or return such as "risk seeking", "risk averse" and "risk neutral" by applying the interactive phase toward investors. Also, to reduce the investors' burden in this interactive phase, the cluster analysis method was proposed to narrow down the solution space in Pareto frontier which satisfy the investors' preference structure. To apply iGA for portfolio optimization problems, we proposed a two-layered chromosome representation. The first layer represents index set that figure candidacy brands of investments. The second layer represents the amount of investment for each brand which satisfy the total budget of investment.

Further, we developed an interactive system that present investment plan suitable for the investors based on his/her preference structure and show the effectiveness of the system.

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# Job Stressors and Job Performance: Modeling of Moderating Mediation Effects of Stress Mindset

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## ABSTRACT

This study examines the moderated effect of stress mindset on the indirect relationship between job stressors and job performance mediated by job satisfaction. Data were collected from 487 employees from the different occupation in Taiwan. Statistical analyses using SPSS and Mplus for model testing, the results show that there is a moderated mediation effect exist. Findings suggested that positive relationship between challenge stressors and outcomes stronger when negative stress mindset is low, and negative relationship between hindrance stressors and outcomes weaker when positive stress mindset is high. Based on the research findings, implications and suggestions for theoretical and practical implication are discussed.

## KEYWORDS

Challenge stressors, Hindrance stressors, stress mindset.

## INTRODUCTION

The issue of job stress is widely concern to academic researcher and practitioner. Kahn, Wolfe, Quinn, Snoek, and Rosenthal (1964) introduced the concept of stressors into organization and management research areas, organizational scholars have increasingly discussed stressors at workplace and developed stress management techniques. Mostly early studies stated that stress is harmful, and has a negative impact on organization and individuals, people must adopt effective strategies to prevent or reduce the incidence of stress (Atkinson, 2004; Bodenmann, Meuwly, Bradbury, Gmelch, & Ledermann, 2010; McEwen & Seeman, 1999; Schwabe & Wolf, 2010). Cooper, Dewe, and O'Driscoll (2001) argued that work stress may affect employee attitudes and physical and mental health. However, prior studies mostly focused on the negative impact of stress but ignored the positive effect of stress may exist.

Some stressors in the workplace contain the elements of growth, can be opportunities for individuals to enhance performance, but some stressors erode employee's passion of the work, may hinder the effectiveness of work. Cavanaugh, Boswell, Roehling, and Boudreau (2000) followed inverted U-shape model (Selye, 1982) and transactional theory of stress (Lazarus & Folkman, 1984), classified job stressors as challenge stressors and hindrance stressors. Challenge stressors have potential growth opportunities for individuals, can guide individual to invest effort into solving problems, result in positive consequences, such as higher job satisfaction (Cavanaugh et al., 2000; Podsakoff, LePine, & LePine, 2007; Webster, Beehr, & Christiansen, 2010); engagement (Crawford, LePine, & Rich, 2010) and performance (LePine, Podsakoff, & LePine, 2005); but lower turnover (Cavanaugh et al., 2000; Podsakoff et al., 2007). Conversely, hindrance stressors will make people stuck with job demand, reduce their work motivation and bring negative results (Podsakoff et al., 2007), such as higher turnover intention, withdraw behaviors (Cavanaugh et al., 2000; Podsakoff et al., 2007), and physical symptoms (Webster et al., 2010); but lower job satisfaction (Cavanaugh et al., 2000; Podsakoff et al., 2007; Webster et al., 2010), engagement (Crawford et al., 2010); motivation (LePine et al., 2005) and job performance (LePine et al., 2005; Pearsall, Ellis, & Stein, 2009; Wallace, Edwards, Arnold, Frazier, & Finch, 2009).

However, according to transactional theory of stress (Lazarus & Folkman, 1984), person's appraisal plays a critical role in the stress process. Although the nature of job stress is sometimes to make people grow, sometimes make people shrink, but we believe that individual perception of stressors is the key factor affecting the follow-up behaviors. Existing research focused less on the moderating effect of individual mindset that affects individual behaviors. Therefore, we considered the boundary conditions in the relationship between stressors and outcomes by introduced the concept of stress mindset, refers as the extent to which one holds the belief that stress has enhancing or debilitating results (Crum, Salovey, & Achor, 2013).

This study contributes to stress research in some ways. First, we integrate the transactional theory of stress and the concept of stress mindset, provide another viewpoint in stress issues. Second, we extend the concept of stress mindset proposed by Crum et al. (2013), which further divided into positive and negative stress mindset. Finally, we give another explanation of boundary condition for the ambiguous results in the relation between stressors and job satisfaction.

## THEORETICAL BACKGROUND AND HYPOTHESIS DEVELOPMENT

### *Transactional theory of stress*

Lazarus and Folkman (1984) proposed transactional theory of stress, defined as an individual's psychological response to a critical situation and where the situation taxes or exceeds the individual's capacity or resources can offer, it is considered a product of the transaction between the individual and the environment. Central to the transactional theory of stress is the idea of cognitive appraisal, namely primary appraisal and secondary appraisal. Lazarus and Folkman (1984) using concepts from expectancy theory (Vroom, 1964), suggested that the initial appraisal process of stressors triggers specific emotional reactions and coping styles that in turn influence behaviors. Primary appraisal is to recognize that situation stressors are potential harm or benefit to the self. Secondary appraisal is then concerned with identifying the appropriate response or coping ways to the specific stressors.

### *Challenge and hindrance stressors*

Cavanaugh et al. (2000) followed Selye (1982) and Lazarus and Folkman's (1984) work, suggested that job stressors have negative and positive effects on work outcomes. They classified work stressors into "challenge" and "hindrance" stressors. Challenge

stressors were defined as “work-related demands or circumstances that, although potentially stressful, have associated potential gains for individuals”, such as workload, time pressure, job responsibility, and job complexity. Hindrance stressors were defined as “work-related demands or circumstances that tend to constrain or interfere with an individual's work achievement and that do not tend to be associated with potential gains for the individual”, for instances, role ambiguity, role conflict, hassles, red tape, organizational politics, and job insecurity (Cavanaugh et al., 2000, p. 68).

Existing studies shown that challenge stressors are positively related to job attitude, such as job satisfaction (Cavanaugh et al., 2000; Podsakoff et al., 2007; Webster et al., 2010), loyalty (Boswell, Olson-Buchanan, & LePine, 2004), organizational commitment (Podsakoff et al., 2007), engagement (Crawford et al., 2010); cognition, such as motivation (LePine et al., 2005), self-efficacy (Webster et al., 2010), organizational justice (Zhang, LePine, Buckman, & Wei, 2014); and behaviors, such as performance (LePine et al., 2005), role-based performance (task performance, citizenship performance, and customer service performance; Wallace et al., 2009), team performance (Pearsall et al., 2009). But, negative effects on job attitude, such as intention to quit (Boswell et al., 2004), turnover intention (Podsakoff et al., 2007); and behaviors, such as job search (Boswell et al., 2004; Cavanaugh et al., 2000), turnover (Cavanaugh et al., 2000; Podsakoff et al., 2007), and work withdrawal behavior (Boswell et al., 2004).

On the other hand, hindrance stressors are positively related to job attitude, such as intention to quit (Boswell et al., 2004), turnover intention (Podsakoff et al., 2007), psychological withdrawal (Pearsall et al., 2009); and behaviors, such as job search (Boswell et al., 2004; Cavanaugh et al., 2000), turnover (Cavanaugh et al., 2000; Podsakoff et al., 2007), withdraw behaviors (Podsakoff et al., 2007), physical symptoms (Webster et al., 2010). Hindrance stressors also have negative effects on job attitude, such as job satisfaction (Cavanaugh et al., 2000; Podsakoff et al., 2007; Webster et al., 2010), loyalty (Boswell et al., 2004), organizational commitment (Podsakoff et al., 2007), engagement (Crawford et al., 2010); cognition, such as motivation (LePine et al., 2005), self-efficacy (Webster et al., 2010), organizational justice (Zhang et al., 2014); and behaviors, such as performance (LePine et al., 2005), role-based performance (task performance, citizenship performance, customer service performance; Wallace et al., 2009), and team performance (Pearsall et al., 2009).

Job satisfaction refers to a psychological state resulting from the evaluation of one's job experiences (Locke, 1976). Based on transactional theory of stress and challenge-hindrance framework, challenge stressors have potential gains for individuals, it should be positively associated with attitudinal and behavioral outcomes. Conversely, hindrance stressors have potential for harm or failure, it is likely to be negatively associated with attitudinal and behavioral outcomes (LePine et al., 2005; Webster et al., 2010; Webster, Beehr, & Love, 2011). According to Lazarus and Folkman (1984), individual will activate initial appraisal process when they face stressors and trigger positive or negative emotional reactions in turn influence behaviors. Challenge stressors provide potential growth opportunities for employees, active employee's enthusiasm for work and positively affect job satisfaction. Conversely, hindrance stressors tend to interfere with employee's work achievement and negatively affect job satisfaction. Prior studies supported that challenge stressors will positively but hindrance stressors will negatively affect job satisfaction (Podsakoff et al., 2007; Webster et al., 2010) and both challenge stressors and hindrance stressors were positively effect on job performance (LePine et al., 2005). We argued that job satisfaction will mediate the effects of stressors on job performance (Fried, Shirom, Gilboa, & Cooper, 2008), and employees who are satisfied with their jobs will enhance their performance in jobs, the recent study also found the similar evidence (Nasir, Khan, & Nasir, 2017). Thus, we proposed hypothesis 1 and 2 as follow.

Hypothesis 1: Job satisfaction mediate the positive relationship between challenge stressors and job performance.

Hypothesis 2: Job satisfaction mediate the negative relationship between hindrance stressors and job performance.

### *Stress mindset*

“Mindset” defines as a mental frame or lens of what we selectively organize and encode information, and guide individual's corresponding actions and responses by a unique way of understanding (Dweck, 2008). Crum et al. (2013) bring the concept of mindset into the field of stress, stress mindset is the extent to which an individual holds the conviction that stress has enhancing or debilitating. They suggested that change one's stress mindset can improve people's response to stress. Specifically, if individual holds a stress-is-enhancing mindset, the primary motivation is to accept and utilize stress toward achieving their goals, brings positive consequence. On the other hand, if individual holds a stress-is-debilitating mindset, the primary motivation is to avoid or manage the stress to prevent negative or debilitating outcomes.

Although two types of stressors affect opposite consequences, existing research found that both challenge and hindrance stressors are positively related to psychological strain (anxiety and emotional exhaustion; Boswell et al., 2004), exhaustion (LePine, LePine, & Jackson, 2004), strain (LePine et al., 2005; Podsakoff et al., 2007), anxiety (Rodell & Judge, 2009), frustration (Webster et al., 2010), burnout (Crawford et al., 2010). According to review paper of Podsakoff et al. (2007), we agree that both challenge stressors and hindrance stressors will increase psychological strain and strain will negatively lead to job satisfaction. However, the mediator variable for strain does not explain that how challenge stressors positively affects job satisfaction and hindrance stressors is negative effect on job satisfaction. We believe that individual's perception of stressors may play an important moderating variable.

The stress mindset measure is developed by Crum et al. (2013), they treated stress-is-enhancing and stress-is-debilitating mindset as the continuum, thus higher score of scale means one's holds stress-is-enhancing, and lower score means mindset of stress-is-debilitating. However, we think that stress mindset should be two independent factors, hence we separated their measure into

positive and negative stress mindset. The individual holds positive stress mindset can bring benefit results, but negative stress mindset will bring damage results. We argue that even though challenge stressors can bring positive outcomes, but if individual hold negative stress mindset, the positive relationship will be debilitating. Even stressors were recognized as promoting growth, negative perception of stressors will damage employee's job satisfaction and the potential successful performance. Reversely, even hindrance stressors will constrain individuals' development and performance, once individual can hold positive stress mindset, at least employee will try to solve the problem. If they think there still have chance to invest effort, depends on our appraisal of how we perceived stressors is helpful or harmful. This can reduce the negative relationship between hindrance stressors and job satisfaction and performance. Thus, we proposed hypothesis 3 and 4 as follow.

Hypothesis 3: Negative stress mindset (NSM) will moderate the positive indirect effect of challenge stressors and job performance mediated by job satisfaction. When NSM is high, the positive indirect effect weakens; when NSM is low, the positive indirect effect is stronger.

Hypothesis 4: Positive stress mindset (PSM) will moderate the negative indirect effect of hindrance stressors and job performance mediated by job satisfaction. When PSM is high, the negative indirect effect weakens; when PSM is low, the negative indirect effect is stronger.

**METHOD**

*Sample and Procedure*

The research participants were general employees and their supervisors. Randomized sampling was used to 530 employees from different occupation, including trading company, restaurants, travel agency, bank, salesperson and staff of gas station and train station in Taiwan. After uncompleted questionnaires were excluded, a final sample was 487 questionnaires was used for data analyses. The employees' demographics showed that 57.6% were females, with an average age of 26.10 years and average work tenure of 4.94 years. Most were single (85.2%) with college education level (76.3%).

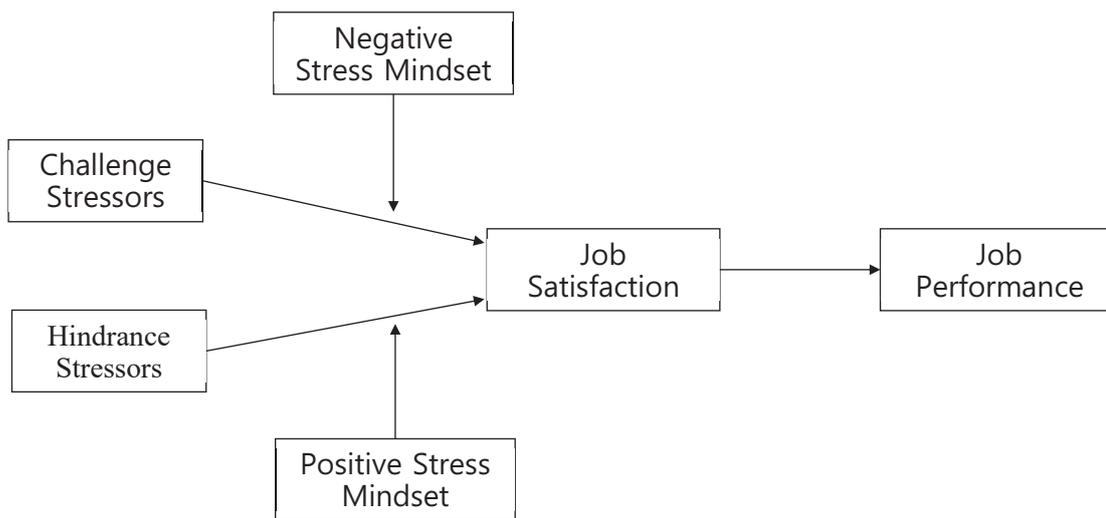


Figure 1 Research framework

*Measure*

*Challenge and hindrance stressors.* Cavanaugh et al. (2000) challenge-hindrance stressors scale was used in our study. There are 6 items measured challenge stressors, a sample item was “The amount of time I spend at work.” The Cronbach’s alpha coefficient was 0.81. On the other hand, 5 items measured hindrance stressors, a sample item was “The lack of job security I have.” The Cronbach’s alpha coefficient was 0.73.

*Positive and negative stress mindset.* We measured stress mindset using the stress mindset measure–general (SMM-G) 8-item scale of Crum et al. (2013), but we treated original four of eight positive items as positive stress mindset and the other four inverted items as negative stress mindset. A sample item of positive stress mindset was “Experiencing stress facilitates my learning and growth.” The Cronbach’s alpha coefficient was 0.69. A sample item of negative stress mindset was “The effects of stress are negative and should be avoided.” The Cronbach’s alpha coefficient was 0.63.

*Job satisfaction.* The 3-item Michigan Organizational Assessment Questionnaire of Camman, Fichman, Jenkins, and Klesh (1979) was used. A sample item was “Overall, I am satisfied with my job.” The Cronbach’s alpha coefficient was 0.78.

*Job performance.* The 5-item job performance scale developed by Viswesvaran, Ones, and Schmidt (1996) was used. A sample item was “My working quality is high.” The Cronbach’s alpha coefficient was 0.70. All variables in this study followed responses

ranging from 1 (strongly disagree) to 5 (strongly agree). *Control variable.* We included the demography control variables, gender, age, tenure, marriage and education.

### Confirmatory Factor Analysis

First, stress mindset was originally loaded onto one factor (Crum et al., 2013), we conducted two-factor CFA to examine whether the eight items were loaded onto two factor. The result indicated that the data fit the two-factor model (chi-square = 169.910, df = 19; CFI = 0.819; NNFI = 0.733; RMSEA = 0.128; SRMR = 0.067) better than one-factor model (chi-square = 528.029, df = 20; CFI = 0.390; NNFI = 0.147; RMSEA = 0.228; SRMR = 0.144).

Second, we examined the validity of our measures by performing a confirmatory factor analysis. Owing to the limited sample size relative to the large number of parameters estimated in the model can be difficult to confirm (Floyd & Widaman, 1995), we created parcels of items (including two or three items for each variable except stress mindset) for analyses. Each parcel was constrained to load onto the latent construct without any error covariance. Table 1 presents a description of the models and their results. Supporting the independence of the six focal constructs, results indicated that the six-factor model (chi-square = 691.694, df = 120; CFI = 0.838; NNFI = 0.793; RMSEA = 0.097; SRMR = 0.091) fit the data better than the other models.

Table 1 Confirmatory factor analysis of nested models

Model	$\chi^2$	df	$\Delta\chi^2$	$\Delta$ df	CFI	NNFI	RMSEA	SRMR
Two-factor model	2242.640***	134	-	-	.401	.316	.177	.181
Three-factor model	1943.792***	132	298.848	2	.485	.403	.165	.159
Four-factor model	1682.967***	129	260.825	3	.558	.476	.155	.148
Five-factor model	1052.628***	125	630.339	4	.736	.677	.122	.132
Six-factor model	691.694***	120	360.934	5	.838	.793	.097	.091

\*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$

Note: CS = Challenge Stressors; HS = Hindrance Stressors; PSM = Positive Stress Mindset; NSM = Negative Stress Mindset; JS = Job Satisfaction; JP = Job Performance.

Two-factor model (CS+HS+PSM+NSM, JS+JP); Three-factor model (CS+HS+PSM+NSM, JS, JP); Four-factor model (CS+HS, PSM+NSM, JS, JP); Five-factor model (CS, HS, PSM+NSM, JS, JP); Six-factor model (CS, HS, PSM, NSM, JS, JP).

## RESULTS

Mean, standard deviation, and correlation of studied variables are shown in Table 2. The correlations for most variables were positive and significant. Except the job satisfaction was negatively correlated to hindrance stressors and negative stress mindset. Besides, there is no correlation between hindrance stressors and negative stress mindset, also challenge stressors and positive stress mindset.

Table 3 shows the results of the hierarchical mediation regression analysis for job performance that were used to test hypotheses 1 and 2. Model 1-2 in Table 3 shows that challenge stressors positively ( $\beta = 0.22$ ,  $SE = 0.05$ ,  $p < 0.001$ ) and hindrance stressors negatively ( $\beta = -0.44$ ,  $SE = 0.04$ ,  $p < 0.001$ ) predicted to job satisfaction. Model 2-3 shows that job satisfaction significantly mediated the relationship between challenge and hindrance stressors and job performance ( $\beta = 0.19$ ,  $SE = 0.03$ ,  $p < 0.001$ ); therefore, hypothesis 1 and 2 were supported.

Regarding hypothesis 3 and 4, we expected NSM would have a moderating effect on the first stage of hypothesis 1 and PSM would have a moderating effect on the first stage of hypothesis 2. The results of hierarchical moderation regression analysis were shown in Table 4. Model 4 in Table 4 shows that the interaction term of challenge stressors and NSM has a significant negative effect on job satisfaction ( $\beta = -0.07$ ,  $SE = 0.02$ ,  $p < 0.01$ ); and another interaction term of hindrance stressors and PSM has a significant positive effect on job satisfaction ( $\beta = 0.06$ ,  $SE = 0.02$ ,  $p < 0.01$ ). We also conducted a hierarchical moderating mediation regression analysis by using Mplus 7.0, the result as shown in Table 5. First, Table 5 shows the interaction term of challenge stressors and NSM has a significant negative moderated effect on job satisfaction ( $\beta = -0.18$ ,  $SE = 0.06$ ,  $p < 0.01$ ). We have plotted this interaction at conditional values of NSM (1 SD above and below the mean) in Figure 2. This graph indicates that the positive indirect relationship between challenge stressors and job performance mediated by job satisfaction is stronger when NSM is low, therefore, hypothesis 3 was supported. On the other hand, Table 5 also shows another interaction term of hindrance stressors and PSM has a significant positive moderated effect on job satisfaction ( $\beta = 0.16$ ,  $SE = 0.07$ ,  $p < 0.05$ ). We also plotted this interaction at conditional values of PSM (1 SD above and below the mean) in Figure 3. This graph indicates that the negative indirect relationship between hindrance stressors and job performance mediated by job satisfaction is stronger when PSM is low, therefore, hypothesis 4 was supported.

Second, to further determine whether NSM and PSM weakened the indirect relationship as predicted by Hypothesis 1 and 2, we considered an alternative moderated mediation model, including the first stage, second stage, direct, indirect, and total effects of the moderator (NSM and PSM). The NSM results shown in Table 6 indicate a pattern consistent with our prediction, with significant effects in the first stage effect (diffidence  $\beta = 0.240$ ,  $SE = 0.078$ ,  $p < 0.01$ ); therefore, hypothesis 3 was supported. The PSM results shown in Table 7, also consistent with our prediction, with significant effects in the first stage effect (diffidence  $\beta = -0.174$ ,  $SE = 0.073$ ,  $p < 0.05$ ); therefore, hypothesis 4 was supported.

Table 2 Means, standard deviations, and correlations among all studied variables

Variables	Means	SD	1	2	3	4	5	6	7	8	9	10	11
1.Gender	1.58	.50	—										
2.Age	26.03	10.71	.03	—									
3.Tenure	4.94	7.87	.05	.88***	—								
4.Marriage	1.15	.36	.06	.81***	.74***	—							
5.Education	2.84	.53	.09	.02	-.09	-.08	—						
6.CS	3.60	.62	.02	.21***	.16***	.16***	.14**	(.81)					
7.HS	2.72	.68	.00	.04	.03	.05	.02	.22***	(.73)				
8.PSM	3.62	.56	-.05	-.08	-.09*	-.11*	.05	.25***	.01	(.69)			
9.NSM	3.06	.68	-.04	.03	.02	.03	-.08	.06	.32***	.13**	(.63)		
10.JS	3.64	.70	-.01	.07	.06	.08	.10*	.11*	-.38***	.37***	-.19***	(.78)	
11.JP	3.57	.54	-.01	.15**	.13**	.08	.12**	.56***	.12**	.38***	.18***	.27***	(.70)

Note: N=487. Reliabilities are reported in parentheses. CS = Challenge Stressors; HS = Hindrance Stressors; PSM = Positive Stress Mindset; NSM = Negative Stress Mindset; JS = Job Satisfaction; JP = Job Performance.

\*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$

Table 3 Results of mediation regression analysis

	Job Satisfaction		Job Performance		
	Model	Model	Model	Model	Model
	1-1	1-2	2-1	2-2	2-3
<i>Control Variable</i>					
Gender	-.05 (.06)	-.05 (.06)	-.03 (.05)	-.03 (.04)	-.02 (.04)
Age	-.00 (.01)	-.00 (.01)	.01 (.01)	.00 (.01)	.00 (.01)
Tenure	.01 (.01)	.00 (.01)	.00 (.01)	.01 (.01)	.01 (.01)
Marriage	.16 (.16)	.21 (.14)	-.10 (.12)	-.10 (.10)	-.14 (.10)
Education	.16 (.06)**	.14 (.06)*	.11 (.05)*	.04 (.04)	.02 (.04)
<i>Independent Variable</i>					
Challenge Stressors		.22 (.05)***		.47 (.03)***	.43 (.03)***
Hindrance Stressors		-.44 (.04)***		-.01 (.03)	.07 (.03)*
<i>Mediator</i>					
Job Satisfaction					.19 (.03)***
R <sup>2</sup>	.02	.20	.04	.32	.37
F	1.98	17.40***	3.80**	31.97***	34.73***
ΔR <sup>2</sup>		.18		.28	.05
ΔF		54.84***		98.54***	37.18***

The regression coefficient is unstandardized coefficient and standard error is reported in parentheses.

\*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$

Second, to further determine whether NSM and PSM weakened the indirect relationship as predicted by Hypothesis 1 and 2, we considered an alternative moderated mediation model, including the first stage, second stage, direct, indirect, and total effects of the moderator (NSM and PSM). The NSM results shown in Table 6 indicate a pattern consistent with our prediction, with significant effects in the first stage effect (diffidence  $\beta = 0.240$ ,  $SE = 0.078$ ,  $p < 0.01$ ); therefore, hypothesis 3 was supported. The PSM results shown in Table 7, also consistent with our prediction, with significant effects in the first stage effect (diffidence  $\beta = -0.174$ ,  $SE = 0.073$ ,  $p < 0.05$ ); therefore, hypothesis 4 was supported.

Table 4 Results of moderation regression analysis

	Job Satisfaction			
	Model 1	Model 2	Model 3	Model 4
<i>Control Variable</i>				
Gender	-.05 (.06)	-.05 (.06)	-.04 (.05)	-.04 (.05)
Age	-.00 (.01)	-.00 (.01)	-.00 (.01)	-.00 (.01)
Tenure	.01 (.01)	.00 (.01)	.00 (.01)	.00 (.01)
Marriage	.16 (.16)	.21 (.14)	.30 (.13)*	.32 (.13)*
Education	.16 (.06)**	.14 (.06)*	.12 (.05)*	.14 (.05)**
<i>Independent Variable</i>				
CS		.13 (.03)***	.05 (.03)†	.05 (.03)†
HS		-.30 (.03)***	-.26 (.03)***	-.25 (.03)***
<i>Moderator</i>				
PSM			.28 (.03)***	.28 (.03)***
NSM			-.09 (.03)**	-.08 (.03)**
<i>Interaction</i>				
CS*PSM				.12 (.02)
CS*NSM				-.07 (.02)**
HS*PSM				.06 (.02)**
HS*NSM				-.02 (.02)
R <sup>2</sup>	.02	.20	.34	.36
F	1.98	17.40***	27.53***	20.81***
ΔR <sup>2</sup>		.18	.14	.02
ΔF		54.84***	50.43***	4.09**

Note. CS = Challenge Stressors; HS = Hindrance Stressors; PSM = Positive Stress Mindset; NSM = Negative Stress Mindset. The regression coefficient is unstandardized coefficient and standard error is reported in parentheses.

†  $p < 0.1$ , \*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$

Table 5 Moderated mediation model results

	Job Satisfaction	Job Performance
<i>Intercepts</i>	-.62 (.23)**	3.56 (.14)***
<i>Control variables</i>		
Gender	-.04 (.05)	-.01 (.04)
Age	-.00 (.01)	.00 (.01)
Tenure	.00 (.01)	.01 (.01)
Marriage	.32 (.16)*	-.09 (.09)
Education	.14 (.06)*	.03 (.04)
<i>Independent variables</i>		
CS	.08 (.05)	.38 (.04)***
HS	-.37 (.05)***	.01 (.04)
<i>Mediator</i>		
JS		.15 (.05)**
<i>Moderator</i>		
PSM	.50 (.06)**	.15 (.05)**
NSM	-.12 (.05)*	.14 (.04)***
<i>Interaction</i>		
CS*PSM	.03 (.07)	.01 (.08)
CS*NSM	-.18 (.06)**	-.02 (.05)
HS*PSM	.16 (.07)*	-.01 (.09)
HS*NSM	-.04 (.05)	.01 (.05)
JS*PSM		-.02 (.08)
JS*NSM		-.12 (.07)†

Note. CS = Challenge Stressors; HS = Hindrance Stressors; JS = Job Satisfaction; PSM = Positive Stress Mindset; NSM = Negative Stress Mindset. The estimate is unstandardized coefficient and standard error is reported in parentheses.

†  $p < 0.1$ , \*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$

Table 6 Overview of significant moderated mediation effects for negative stress mindset

	First Stage Effect	Second Stage Effect	Direct Effect	Indirect Effect	Total Effect
Low_NSM (-1 SD)	.197 (.053)***	.232 (.082)**	.391 (.055)***	.046 (.021)*	.437 (.052)***
High_NSM (+1 SD)	-.043 (.074)	.073 (.049)	.366 (.053)***	-.003 (.007)	.363 (.054)***
Diffidence	.240 (.078)**	.159 (.093)†	.025 (.072)	.049 (.020)*	.074 (.069)

Note. NSM = Negative Stress Mindset (SD= .67780). Standard errors are reported in parentheses.

†  $p < 0.1$ , \*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$

Table 7 Overview of significant moderated mediation effects for positive stress mindset

	First Stage Effect	Second Stage Effect	Direct Effect	Indirect Effect	Total Effect
Low_PSM (-1 SD)	-.456 (.070)***	.162 (.068)*	.021 (.076)	-.074 (.030)*	-.053 (.065)
High_PSM (+1 SD)	-.282 (.055)***	.143 (.067)*	.008 (.051)	-.040 (.018)*	-.032 (.047)
Diffidence	-.174 (.073)*	.019 (.093)	.013 (.101)	-.034 (.034)	-.021 (.083)

Note. PSM = Positive Stress Mindset (SD= .56233). Standard errors are reported in parentheses.

\*  $p < 0.05$ , \*\*  $p < 0.01$ , \*\*\*  $p < 0.001$

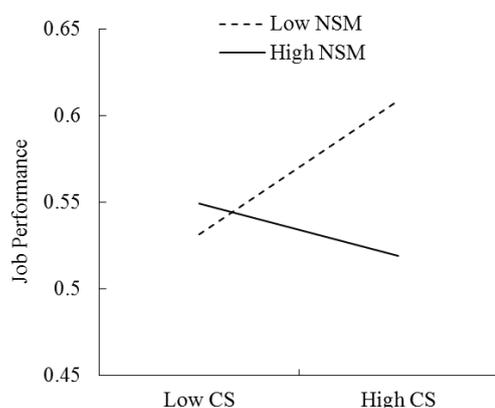


Figure 2 Negative stress mindset (NSM) moderates the mediation effect of job satisfaction between challenge stressors (CS) and job performance.

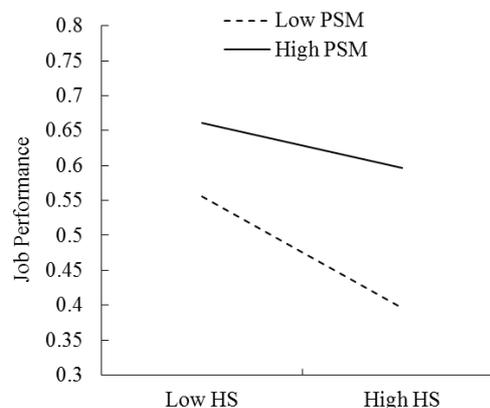


Figure 3 Positive stress mindset (PSM) moderates the mediation effect of job satisfaction between hindrance stressors (HS) and job performance.

## DISCUSSION

This study integrates the transactional theory of stress and the concept of stress mindset to investigate the moderating mediation model. First, our results suggested that job satisfaction mediated the positive relationship between challenge stressors and job performance, also mediated the negative relationship between hindrance stressors and job performance. Second, we introduce concept of stress mindset proposed by Crum et al. (2013), and further divided into positive and negative stress mindset. Our findings reveal that individual's different stress mindset of stressors plays a critical moderating role during the process of pursuit working goal. Once individual hold a negative stress mindset, the positive mediation will become weaker; reversely, holding a positive stress mindset can help the negative mediation become weaker.

### Theoretical implication

First, existing studies lack empirical evidence to link the relationship between challenge-hindrance framework, job satisfaction and job performance, and our study fills this research gap. According to the transactional theory of stress (Lazarus & Folkman, 1984), individual will appraise the stressors they encounter, challenge stressors can trigger positive emotion and lead to positive outcomes; hindrance stressors will trigger negative emotion and result in bad outcomes. Our findings suggested that challenge stressors can positive affect job satisfaction and enhance job performance, but hindrance stressors will damage employee's job satisfaction and reduce job performance, which extends the existing studies (Fried et al., 2008; LePine et al., 2005; Podsakoff et al., 2007; Webster et al., 2010).

Second, Crum et al. (2013) bring concept of mindset into stress issue, they suggested that one's mindset tend to stress-is-enhancing will lead to positive consequence; conversely, one's mindset tend to stress-is-debilitating will lead to negative outcomes. We agree with Crum et al. (2013), and argue that different stress mindset can result in different behaviors. However, we don't agree with Crum et al. (2013) the methodological way they employed which treated stress mindset as a spectrum, the degree of stress-is-enhancing or stress-is-debilitating. We divided stress mindset scale into positive and negative two factors, and the result of the confirmatory factor analysis also support our idea. Therefore, we refined Crum et al. (2013) stress mindset measures, provide future researchers with another option.

Furthermore, we give an explanation for the ambiguous results in the relation between two types of stressors and job satisfaction (Podsakoff et al., 2007). Result shows that stress mindset is a boundary condition that moderate the relationship between stressors and job satisfaction. Even challenge stressors were recognized as "good" stress and can lead to beneficial consequence, but if one's hold negative stress mindset, this positive relationship will be impaired. Conversely, hindrance stressors was treated as "bad" stress and brings damage outcomes, but if employee can hold positive stress mindset, this negative relationship will be repaired.

#### *Empirical implication*

Our findings suggested that job satisfaction mediated the relationship between challenge/hindrance stressors and job performance. In practice, the organization should try to provide employee more growth and development opportunities for the job, such as setting timeliness of task completion, increase job responsibility or complexity of task, these challenge stressors can make working situation become more challenging. This paper also presents that stress mindset can affect individual's attitude and consequences behaviors. Consequently, organization could assist employee to establish positive mindset or develop positive thinking by organize learning activity or set up psychological counseling units to help employees rethink the stressors they faced.

#### *Limitations and suggestion for future research*

There are still some research limitations in this study. First, our research variables are derived from employee self-reporting, may lead to common methods variance concerns, especially job performance may have inflation effect. We suggest future study should use supervisor-employee dyad questionnaire to exclude common sources concerns. Second, we divided stress mindset scale into two factors without pilot study to ensure the reliability of the scale. Although the confirmatory factor analysis shows two-factor model is preferred, but we recommended the follow-up studies should be categorized in a more rigorous manner. Third, our sample only for Taiwanese employees, the results may not be enough to generalize to other countries, suggesting that future research should increase the research sample to increase the external validity.

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# A Study on the Changes of Online Public Opinion in the Postwar Crisis of Companies Using Opinion Mining

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## ABSTRACT

Crisis is an inescapable task for a company, and how it overcomes crises often leads to new growth of the company or to its survival. As new media such as SNS are activated, information and sharing of people are getting more and more. If a company can objectively analyze consumer opinions generated online through big data and detect negative emotions in advance, the company will be able to cope with the crisis more appropriately when a crisis occurs. I collected the relevant texts by selecting the domestic manufacturing companies 'Samsung Electronics' and 'Hyundai Motors' as keywords, and analyzed frequency analysis, LDA topic modeling analysis and sentiment analysis using the crisis detection monitoring system and emotion algorithm presented in this study.

As a result of analyzing the frequency of collected data related to the keyword, it is difficult to detect the potential crisis of the company as the number of news articles. However, when the frequency of comment of news articles increases rapidly or the amount of Twitter buzzword surges, and it was confirmed that there could be a potential risk factor. I analyzed topics extracted from the comments of news articles through topic modeling method, and we could more clearly identify the topics that constitute the topic of what issues people think about the company at the time of collection.

This suggests that the emotional intensity of people responding to negative corporate issues is higher when they are exposed to the media. This is because it is difficult to confirm the number of simple comments and news stories.

Keywords : Corporate Crisis, Sentiment Analysis, Opinion Mining

## I. INTRODUCTION

### *1.1 Research background*

Information or news from portal sites and communities where information can be easily accessed, and people visit often, plays an important role in forming the image of a company in the public's mind. Previously, information that was filtered by the press was accessed through limited media. However, nowadays, in our environment, we can access any time information that is generated in various online channels, and companies are increasingly facing difficulties in coping with numerous online access points. Because such social media is a medium that makes possible the formation of relationships through mutual interactions, companies need to perceive it as a main channel whereby crisis communication strategies can be implemented. However, many companies are

merely recognizing it as a field of marketing and advertisement; they lack understanding as to utilizing social media as a channel of crisis management. To them, a crisis was just an encumbrance to be hidden, and their efforts to preliminarily prevent a crisis and to calibrate the state of crisis into new opportunities were insufficient. In other words, there was a strong tendency among domestic companies to critically address crisis management, only after a large risk or incident took place. Thus, there needs to be a discussion as regards a plan for companies to use big data in recognizing the crisis beforehand and finding fast and quick countermeasures.

### *1.2 The purpose of the research*

The purpose of this research is to check whether big data generated online can be analyzed for companies to recognize the crisis preliminarily and to check change in public opinion in the internet before and after crisis management of a company.

As regards existing researches, there is a limitation that it is difficult to reflect the natural context of use upon experiments and surveys. On the other hand, as regards online data such as Twitter and comments on internet news, there is an advantage that user opinions on which the context is reflected can be recognized. In order to analyze the flow of online public opinion and check crisis management strategies of companies, I used the sentiment analysis method of opinion mining to collect unstructured data – comments, mentions, etc. Also, through the topic modeling, I checked whether potential crisis factors of companies can be perceived.

### *1.3 The range and methods of the research*

Using the opinion mining technology, I proposed the sentiment analysis algorithm by which subjective opinions of product users can be automatically classified and analyzed, thereby allowing the crisis of a company to be perceived. I constructed a monitoring system, and as research objects selected Samsung Electronics and Hyundai Motors, and collected and analyzed data. Because both companies are sensitive to negative opinions, I thought them appropriate and thus, selected them as research objects. As regards data, I used the research API provided by Twitter and the news portal run by Naver, the major portal in Korea. I collected mentions in Twitter and the texts of and comments on Naver news for three months, between August, 2016 to October of the same year, and classified data into 5 sentiment types – anger, dissatisfaction, anxiety, disappointment and positivity. I extracted sentiment levels of the texts by supplementing the number of agreements and disagreements. In order to achieve the purpose of this research, the following questions were asked.

First of all, is the sentiment analysis algorithm proposed in this research appropriate to be a tool for crisis management, such as quick recognition of a crisis by a company upon its occurrence, and proposition of countermeasures?

Second of all, how did the online image of the companies changed before and after the incident, the companies that coped with

the crisis based on actual company data through the countermeasure monitoring system proposed in this research? What change is there as regards the direction of public opinion, according to crisis management strategies of a company?

Lastly, are domestic companies appropriately managing crisis in order to respond to negative comments on companies generated online?

## **II. CONSIDERATION ON PREVIOUS RESEARCHES**

### *2.1 The crisis of a company*

Lerbinger classified crisis into seven categories: natural disaster, technological crisis, confrontation, malevolence, management misconduct, rumors, and skewed management values. Linke also made classifications such as exploding crisis, immediate crisis, building crisis and continuing crisis. Coombs classified crisis into nine categories: natural disaster, technical-error accidents, malevolence, human-error accidents, challenges, rumor, workplace violence, injuries and management misconduct.

### *2.2 Product-harm crisis*

The theory that explains the product-harm crisis is attribution theory, which seeks to explain the response of customers on product failure (mainly dissatisfaction with the product), and countermeasures of the companies. I assumed that the attitude toward failure changed according to whether the cause of the crisis occurred internally or externally, or whether it was stable or unstable.

Consumers inferred the cause of product failure from three dimensions: stability, locus and controllability. Through this an useful theoretical framework is provided by which casual relations are explained as to why a communicator clarifies a certain position as regards a particular issue (Kelley 1967, Kelley 1972).

### *2.3 Discussion on expansion of influence of new media*

One of the advantages of SNS is that facts can be delivered quickly and realistically. This is providing new opportunities for reporters to report in a new fashion. Users of SNS are no longer merely recipients who passively access news, but their role is evolving to informant and participant who actively provide news. Through specific medium, online minor opinions can exert influence, for topics of the individual dimension can be developed to those of the public dimension. In that regard, main factors that affect crisis of a company can occur online, and in order to perceive this preliminarily, constant monitoring on online users' opinions is needed.

### *2.4 Opinion mining and sentiment analysis*

Opinion mining is a process of extracting, classifying, understanding and capitalizing opinions that users have expressed through several media. It is a method of text mining technique. Opinion mining is used to identify sentiments, emotions, thoughts and feelings inside online texts produced by users. It is especially used a lot to trace sentiment directions as regards public opinion in

SNS.

Sentiment analysis is an analysis process in opinion mining by which sentiments expressed in text are perceived, thereby perceiving whether sentiment of the text in question as regards a certain topic is positive or negative. Characteristics are extracted and polarity of emotions is found. The sentiment dictionary used to analyze sentiment affects largely analysis results and accuracy. Research to build the sentiment dictionary is, on the whole, divided into two types: one to classify words into three sentiment categories, positive, negative and neutral, and the other to quantify intensity of sentiment polarity.

Recently, sentiment analysis is being conducted a lot based on machine learning. This can be classified into supervised learning and unsupervised learning. For supervised learning, using learning data in which emotions are already differentiated in the document, the classifier is taught, and using the classification model produced, data to be actually tested is classified and differentiated. Unsupervised learning is a sentiment analysis method based on dictionary, which can be classified into natural language processing and statistical approach.

Also, according to the analysis method, sentiment analysis can be divided into 4 categories.

<i>Sentiment Analysis Methods</i>	<i>Features</i>
<i>Keyword-based Analysis</i>	<i>Analysis of Words Using Sentiment Dictionaries</i>
<i>Word Association Analysis</i>	<i>Analysis of Using Word Co-Occurrence Frequency</i>
<i>Statistical Analysis</i>	<i>Analysis of Using Supervised Learning-based Algorithm</i>
<i>Manual Analysis</i>	<i>Analysis of Using Evaluator Manual</i>

Table 1. Sentiment Analysis Methods

As such, sentiment analysis is a process by which valuable information is extracted from opinions of many unspecified users, in other words, unstructured data. It is useful in quickly grasping opinions or preferences of users as regards particular product or service of a company.

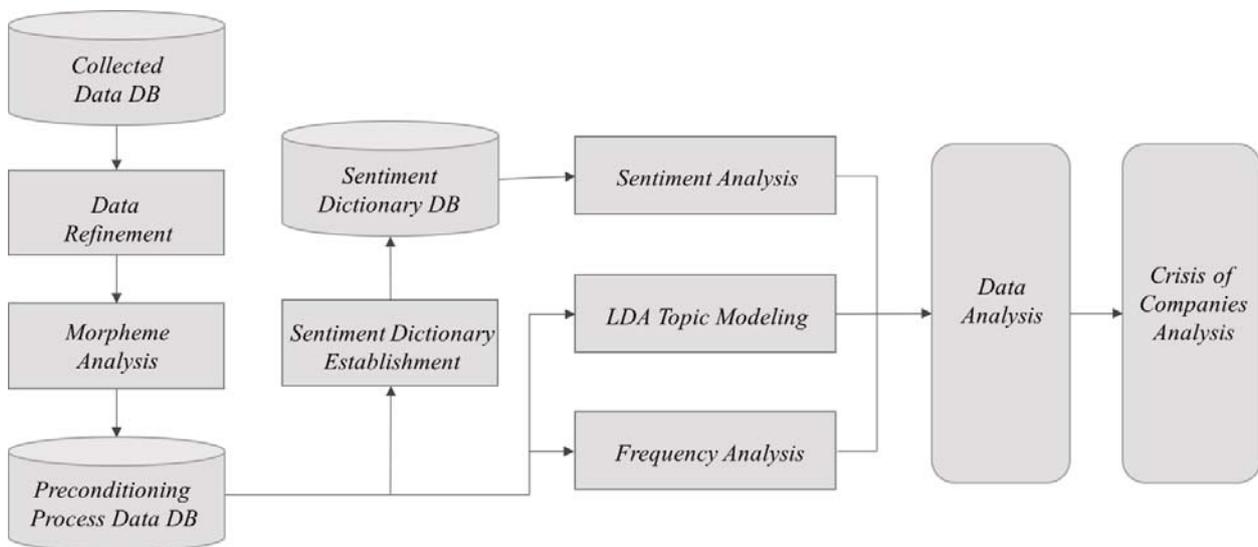
### III. RESEARCH METHOD

In this research, I compared cases of several companies using sentiment analysis algorithm in order to check how online public opinion changes according to the method a company employs to overcome crisis which happens when an issue is spread

throughout online. For three months, from August, 2016 to October of the same year, I collected the texts of and comments on news articles including keywords, ‘Samsung Electronics’ and ‘Hyundai Motors’, from Twitter and Naver portal news. Also, via analysis of morphemes and text mining, I built a sentiment dictionary.

### 3.1 Research model

I collected Naver news articles and texts of comments and through analysis of morphemes analyzed mutual relations between the frequency of key words and the company issue. I also analyzed topic modeling and conducted sentiment analysis so as to check how people’s opinions as regards a company changes from before to after the occurrence of an issue. The process of this research is expressed in Picture 1.



Picture 1. Company Monitoring System and Research Process

### 3.2 Collection of data

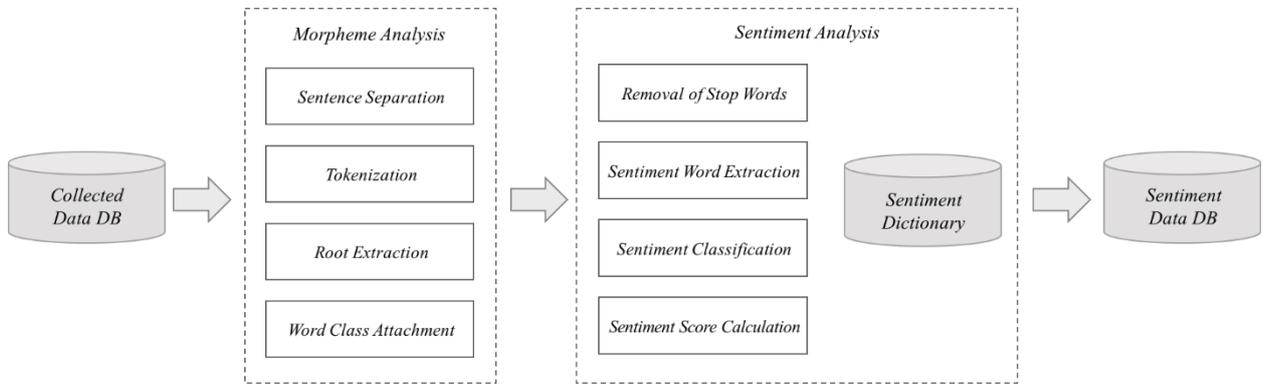
For three months, from August 1st, 2016 to October 31<sup>st</sup> of the same year, I collected article texts and information on comments that show people’s emotions and opinions. For collection of data, I used a research API module, and collected by realizing a web crawler with Python. For the first preprocessing activity, I eliminated unrelated, unnecessary information, and for the second preprocessing activity, I eliminated overlapping information, special characters and stop words.

### 3.3 Morphological analysis

Morphological analysis is the process of grasping a structure of various linguistic characteristics, such as morphemes, etymons, prefixes/suffixes and POS. Through the process of analyzing Korean, by which a string form is divided into minimum units that could be analyzed, and through the process of morphological analysis, by which these are divided into morphemes according to function/form /meaning, I conducted natural language processing. Data was extracted from the morphological analysis.

### 3.4 Constructing sentiment dictionary and analyzing sentiment

A sentiment feature refers to a characteristic that shows whether sentiments can be classified based on the implication of a vocabulary. An emotion term refers to a term that expresses an emotion and a cluster of emotion terms becomes an important terminological asset that can be used for classifying emotions as sentiment features.



Picture 2. Sentiment Analysis Methods

According to relevance of sentiment expression and the standard of actual use, I selected final 675 terms, and used them for construction of sentiment dictionary. For selected 675 terms, I made 5 sentiment classifications through a survey, and constructed the sentiment dictionary. 229 emotion terms classified as positive and 445 emotion terms classified as negative were selected.

<i>Large Category</i>	<i>Middle Category</i>	<i>Number</i>	<i>Weight</i>
<i>Positive</i>	<i>Positive</i>	229	-1
<i>Negative</i>	<i>Anger</i>	146	+4
	<i>Disappointed</i>	95	+1
	<i>Dissatisfaction</i>	114	+3
	<i>Anxiety</i>	90	+2

Table 2. The Number of Words by Each Sentiment Category

### 3.5 Topic modeling

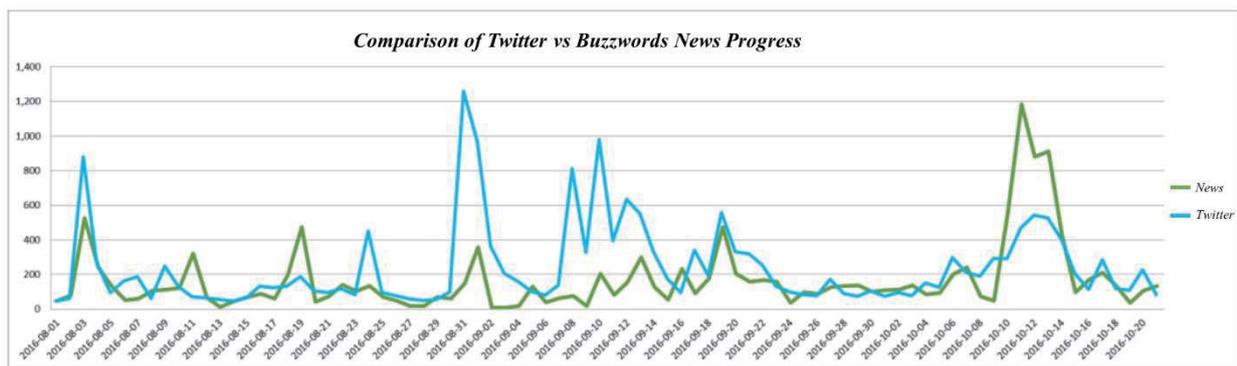
In this research, in order to analyze the dispersion of discussion topics tied in with people’s perceptions on the company before

and after the occurrence of the company crisis, I used the LDA topic modeling algorithm of MALLET. Through the morpheme analyzer I calibrated comments on a news article so that only nouns and verbs could be selected, and based on this data, I carried out LDA topic modeling. As regards key words that were extracted through this process, I designated appropriate topic names. I compared topics that appeared in comments on news articles about Samsung Electronics and Hyundai Motors, thereby analyzing differences and connections.

#### IV. RESEARCH RESULT

In this research, I constructed the monitoring system for detection of a company crisis and the sentiment algorithm. I examined their function as tools in order to check whether they, as tools to respond to a crisis of a company upon its occurrence, can perform the role of detecting a signal of the crisis. Also, by analyzing actual cases of companies, I checked change in public opinion in the internet as regards a company, corresponding to crisis management strategies, and contemplated upon directions companies should take in their crisis management.

In this research I inserted the names of the companies in question or of issues, such as “Samsung Electronics” and “the explosion of Note 7. I used specific terms so that I could, on the whole, check issues related to the companies. In order to analyze data that is suitable for detecting a crisis of a company, I collected texts registered in Naver portal news and Twitter, thereby accessing to opinions of various people. If you look at Picture 3 that shows the comparison, you can see that buzzword occurrence patterns of Twitter and Naver News are similar.



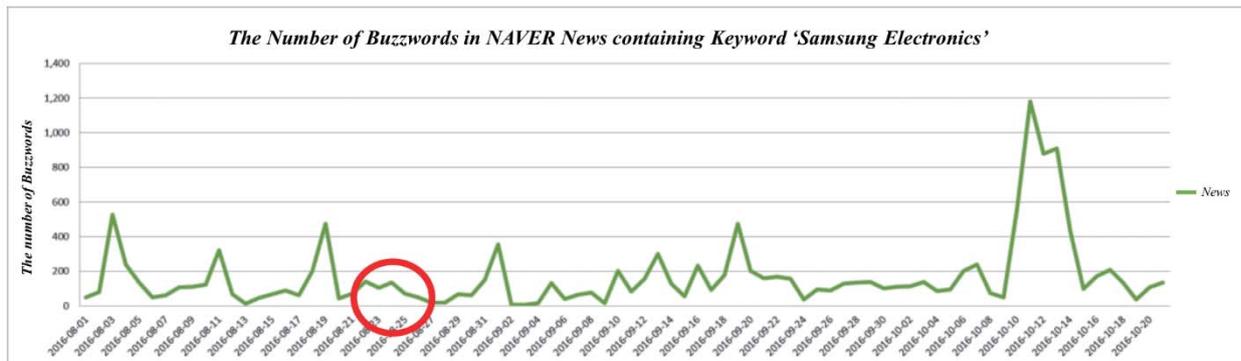
Picture 3. Comparison of the Number of Twitter and NAVER News with Key Word Search ‘Samsung Electronics’

It seems that issues that have taken place in SNS are quickly spread to online news articles, and between both media, there was not much difference in what preceded or followed. By making more specific the timing when abnormal signs began to appear, I analyzed the cause behind emotions people had expressed and abnormal patterns.

##### 4.1 Analysis of crisis of Samsung Electronics with big data

#### 4.1.1 The result of frequency analysis

Based on data collected/processed by research API provided by Naver, I found out that the number of occurrence of news articles related to Samsung Electronics was approximately 167 per day. Picture 4 shows the frequency of news related to the keyword “Samsung Electronics”, the object of analysis in this research, according to a date.



Picture 4. The Frequency of ‘Samsung Electronics’ News by Date

If you look at the frequency of occurrence of news articles, you can see that the frequency of related news has rapidly risen. If you look through the news on the date in question, you can see that a considerable number of news articles are related to the incident of battery explosion of the product “Galaxy Note 7”. Thus, I realized that many people were concerned with product failure of a company. Especially on October 11<sup>th</sup>, when Samsung Electronics officially admitted discontinuation of the product and loss, a considerable number of related news articles occurred, reaching the highest frequency.

#### 4.1.2 The result of topic analysis

In this segment, as I assumed that the battery failure issue of the product “Galaxy Note 7”, of which existence I checked as a result of analyzing the frequency, could lead to crisis of a company, I checked how the main topic of comments people left on news articles had changed from before to after the first battery explosion incident. I looked for possibilities as to whether with the topic in question, the crisis of the related product can be preliminarily detected. From collected data, through the KOMORAN 3.0 morpheme analyzer, I only collected segments involving nouns and verbs, and using MALLET library, I implemented topic modeling so as to extract topics.

#### 4.1.3 The result of sentiment analysis

I constructed the sentiment analysis system and created sentiment dictionary by classifying emotion terms into ‘positive’, ‘anger’, ‘disappointment’, ‘anxiety’, and ‘dissatisfaction’. I also endowed the number of agreements and disagreements in comments on news articles with weighted values, distinguishing the sentiment score.

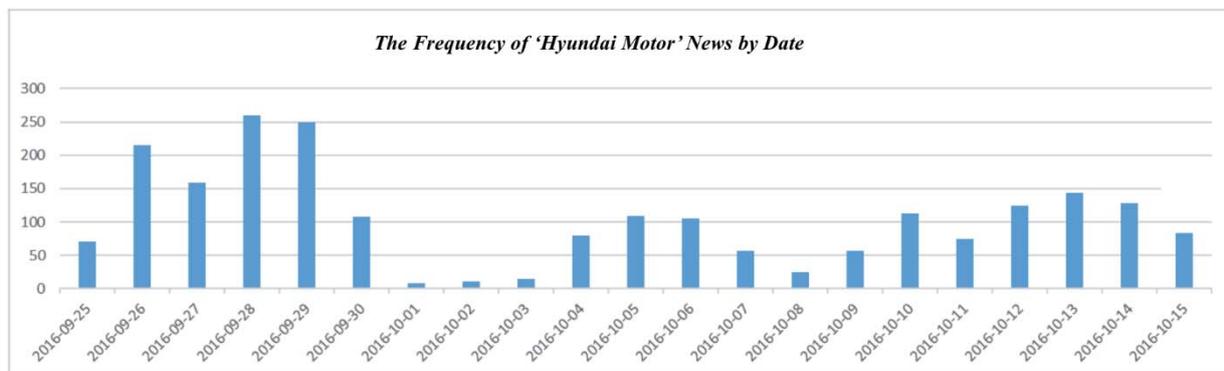
Based on this, I carried out sentiment analysis as regards 12,614 comments on news articles (August 21<sup>st</sup>, 2016 ~ August 26<sup>th</sup>, 2016) related to Samsung electronics before and after the Galaxy Note 7 battery explosion incident (happened on August 24<sup>th</sup>). In the early period of the release of Samsung Electronics' product "Galaxy Note 7", there were many positive emotion terms. As a result, on August 21<sup>st</sup>, the sentiment score was low, being -116. However, after the battery explosion issue had occurred on August 24<sup>th</sup>, the score jumped up to 6712. Emotion terms such as anger, dissatisfaction and anxiety increased, making the gap between sentiment scores according to dates larger.

#### 4.2 The analysis of the crisis of Hyundai Motors with big data

##### 4.2.1 The result of the frequency analysis

I analyzed with the same method that was used in analyzing the case of Samsung Electronics mentioned above. As a result, I found out that excluding overlaps, the frequency of occurrence of news articles related to Hyundai Motors was approximately 104 per day.

Picture 5 shows the frequency of news according to date related to the keyword "Hyundai Motors", which was selected as the object of analysis for this research. Especially, on September 26<sup>th</sup> and October 13<sup>th</sup>, the points when the labor strike against Hyundai Motors initiated and ended, considerable numbers of news articles occurred, reaching the highest frequency.



Picture 5. The Frequency of 'Hyundai Motor' News by Date

In the comments, there was a high proportion of terms related to labor union, such as "labor aristocrats", "suspension of negotiation", and "temporary workers". As a result, I found out that many people were concerned particularly with issues as regards Hyundai Motors' management and ethics.

##### 4.2.2 The result of topic analysis

It is difficult to preliminarily detect a crisis of a company, simply by using frequencies, such as a number of comments on news

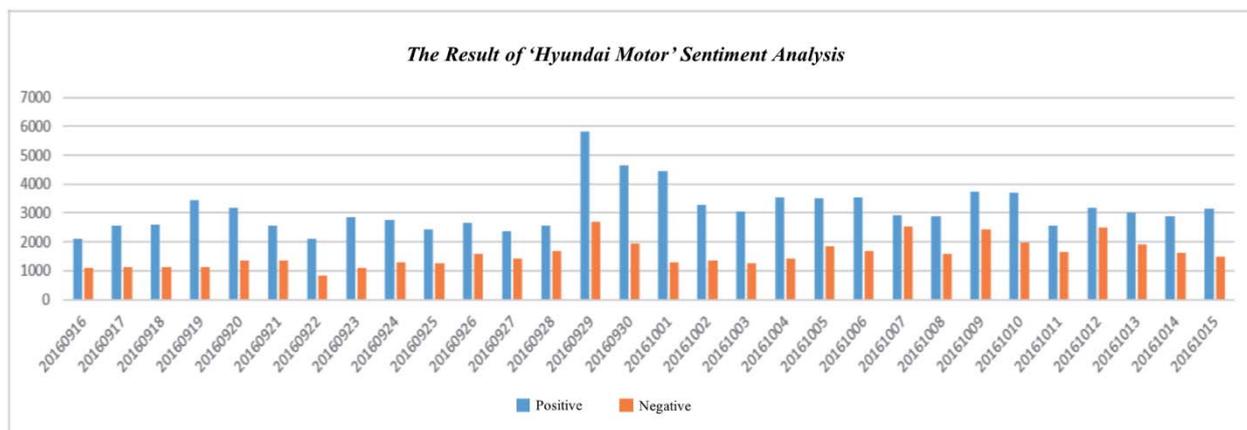
articles and a number of news articles. This is because although their opinions are reflected on comments, the intentions can be grasped only after understanding the context of a text in question.

In this segment, as I assumed that “the labor strike against Hyundai Motors” could lead to the crisis of the company, I checked what change occurred in the main topic of people’s comments on news articles from before to after the occurrence of the labor strike. Also, I analyzed what implications could be found.

In sentences selected based on verbs and nouns, a considerable number of abbreviations and neologisms were included, so I had to implement by modifying dictionary several times. I endowed topic names, by considering semantic connections. If you look at the topic model of news comments before and after the labor strike against Hyundai Motors, you can see that after the strike the number of comments related to the labor strike including terms such as ‘labor aristocrats’ and ‘engine oil’ had largely increased, and that the terms became more specific.

#### 4.2.3 The result of sentiment analysis

As in Picture 6, during the period of collection, in comments on news articles related to Hyundai Motors, overall, there were more positive terms than negative ones. However, as in October 7<sup>th</sup>, whenever news as regards the labor strike appeared, negative comments increased.



Picture 6. Trends in the Number of Positive/Negative Words of ‘Hyundai Motor’ Related Comments

Also, peculiarly, on October 9<sup>th</sup>, despite the fact that, as you can see from the dispersion of sentiments of comments, there were 1,000 positive terms, resulting in a high score, negative emotion terms such as anger, dissatisfaction, and anxiety increased, making the high sentiment score of 1499.

<i>Date</i>	<i># of News Articles</i>	<i># of Comments</i>	<i>Positive</i>	<i>Anger</i>	<i>Disappointed</i>	<i>Dissatisfaction</i>	<i>Anxiety</i>	<i>Sentiment Score</i>
2016-10-08	25	290	77	17	0	171	171	846
2016-10-09	50	655	1000	262	0	79	607	1499
2016-10-10	118	2185	988	257	32	98	551	1468
2016-10-11	73	1334	440	133	13	50	246	747
2016-10-12	115	1264	178	197	0	228	24	1342
2016-10-13	136	1858	205	113	0	586	94	2193
2016-10-14	123	1412	224	71	17	77	33	374

Table 3. Distribution of Emotion Terms Comments of ‘Hyundai Motors’ Related News

The cause can be found in the news article on the date in question, on the outcome of the case of Chinese/American Hyundai Motors engine. As to this issue, Hyundai Motors made a defensive position, stating that “this does not apply to domestic products”. I checked that a considerable number of comments that expressed negative emotions, such as anger and anxiety, occurred as to the article in question. Consequentially, judging from the fact that the number of negative comments had skyrocketed, it seemed that public opinion in the internet was not favorable.

As a result, in the case of Hyundai Motors, it seems that people are more negatively reacting to the labor strike than they react to product failure. Rather, the issue about product failure received attention only for awhile. Thus, defensive crisis management strategies of Hyundai Motors seem to be, at times, methods appropriate.

## V. CONCLUSION AND SUGGESTION

In this research, in order to find ways to preliminarily detect a crisis of a company, I selected as keywords ‘Samsung Electronics’ and ‘Hyundai Motors’, major domestic manufacturing companies. Also, I collected from information on Naver portal news articles and comments and Twitter mentions texts including the keywords. Using the monitoring system for crisis detection and the sentiment algorithm I developed for this research, I carried out three types of analysis: frequency analysis, LDA topic

modeling analysis and sentiment analysis.

First of all, I analyzed frequency of collected data related to the keywords. As a result, I found out that although it is difficult to detect potential crisis simply by observing the number of news articles, in the case where frequency of comments on news articles rapidly increased or the number of Twitter buzzword rapidly increased, potential crisis factors could possibly be discovered.

Through the topic modeling method, I could more clearly check terms that constituted the topics, which allowed me to figure out issues people were thinking about as to a company. As such, through the topic analysis, it was possible to check, based on the number of topic classifications, on which issue related to a crisis of a company attention was increasing or decreasing. Through sentiment dictionary, I could check that when a negative issue as to a company was exposed in media, the sentiment intensity of opinions reflecting people's reactions increased; it was difficult to do so just by checking the number of comments and of news articles.

According to a way a company managed a crisis, there was difference in the dispersion of emotion terms from people's comments. In the case of Samsung Electronics, before the announcement of recall on the product Galaxy Note 7, there were many negative emotion terms, producing a high sentiment score. However, after the company officially admitted product failure and announced recall, the sentiment score rapidly decreased and the number of positive comments increased. On the other hand, in the case of the issue of engine failure of Hyundai Motors, the company used defensive strategies, denying the contentions. This resulted in rapid decrease in attention as to product failure, as another issue arose to the surface, which was about the labor strike.

It appeared that at times, defensive crisis management strategies of Hyundai Motors were methods appropriate to overcome a crisis of the company. In the case of sentiment dictionary based on terms used for this research, even if terms were constantly supplemented, there was a restriction in accurately grasping contexts of some sentences. There were a considerable number of sentences in which a considerable number of negative terms were included, but in the actual context, had positive implications. In the future research, there needs to be analysis of the contextual implications of sentences.

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# Exploring Best-Fit Recommendation Mechanisms in Different E-Commerce Scenarios

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## ABSTRACT

E-commerce websites tend to develop a deeper understanding of customers by collecting personal data and then recommend personalized products. However, personalized recommendation mechanisms may not be welcomed by all customers due to incorrect or unrelated recommendation, privacy concerns, or threats of being monitored. This research aims to understand customers' attitude toward three different online recommendation mechanisms (RM): One-to-All, One-to-Many and One-to-One under different online purchasing scenarios. Drawing on resource-matching theory, we first hypothesize that the perceived usefulness of the three RMs are different. We then further examined three moderation effects – complexity, familiarity and external information acquirement to understand how customers' perceived usefulness of the three RMs may vary. We conducted an experiment including 2(high, low complexity) \* 2(high, low familiarity) \* 2(with, without external information) scenarios. All respondents are asked to fill out a questionnaire before and after conducting a designated task to measure their perceived usefulness of each RM. Overall, our results show that customers perceive highest usefulness from the One-to-Many RM. However, in each scenario, customers tend to change how they perceive the usefulness of each RM. Our results provide managerial insights to e-commerce vendors for how to design the best fit recommendation mechanisms under different shopping scenarios.

## KEYWORDS

Personalization, Recommendation, Resource Matching Theory,

## INTRODUCTION

Striving to satisfy customers' needs, businesses try various approaches to know their customers better. E-commerce vendors, in particular, collect customers' data explicitly or implicitly to accelerate consumers' motives for purchase (Lee & Kwon, 2007). Personalization has been used as a powerful tool in marketing area (Schafer, Ben, Konstan, & Riedl, 2001). It is argued that providing personalized information can have many benefits for customer engagement, experience and revenue (Nielson, 2016). However, from consumers' point-of-view, their intention toward accepting those recommended content vary (Xiao & Benbasat, 2007). Personalized recommendation can be disturbing advertisements or irrelevant information that obstruct user experience. Thus, the objective of this research is to investigate under what conditions customers rely on personalized recommendation most and to what extent.

Based on resource matching theory, we designed an experiment asking participants to buy products under different circumstances. Three manipulated variables were used in the experiment: Familiarity, External Information and Complexity. In other words, the experiment includes eight scenarios: 2(high, low familiarity) \* 2(with, without external information) \* 2(high, low complexity). Participants were asked to evaluate different recommendation mechanisms under the eight scenarios. The results show that perceived usefulness of each recommendation mechanism varied. Our results provide managerial insights to e-commerce vendors for how to design the best fit recommendation mechanisms under different shopping scenarios.

## THEORETICAL BACKGROUND

### *Resource-Matching Theory (RMT)*

Resource-Matching Theory (RMT) describes that consumer have finite cognitive resources to process information and carry out information-related tasks (Zhu, Nakata, Sivakumar, & Grewal, 2007). RMT states that judgments are affected by the balance between the cognitive resources available and those required from a given task (Anand and Sternthal, 1989). Information processing is most efficient when cognitive resources

available and demanded best match. That is, if a task requires more mental efforts, the more cognitive resources are needed to achieve the balance. Therefore, the effectiveness of recommendation mechanisms depends on the match of customers' shopping cognitive capacity and the resources available to carry out the task.

When applying RMT to e-commerce practices, customers should have competent cognitive resources to conduct purchasing tasks. As the number of online selling product grows, much more variant attribute of products emerges. The amount of product attributes relates to customers' decision making process directly; when selecting products, customers have to learn and digest provided information of different product attributes. Facing a considerable amount of information, customers without sufficient cognitive resources might feel information overload. An experiment conducted by Lee and Lee (2004) asked participants to choose a best CD player in a given task shows that the number of attributes is a competent indicator of the effect of information overload on customer choice. The unbalance between customers' cognitive resources and task demands leads to customers' searching behavior of finding more resources.

Searching for information is a critical step in customer' decision making process (Park & Stoel, 2005). Customers search for reasons. Obtaining information not only helps customers to reduce information overload but also increase their decision quality (Xiao & Benbasat, 2007). Behavioral scientists have shown that since online shoppers are unable to touch or feel physical products before buying, they may tend to find additional information for help. Two types of information searching behaviors are studied, internal search and external search in Engel et al. (2000) study. Resources from internal search involves memory and occurs prior to external information search (Peterson & Merino, 2003). Resources from external search can be collected from reference group (e.g. friends, experts) and/or other marketplaces (e.g. product description, sales performance) (Park & Stoel, 2005).

When applying RMT to the context of recommendation mechanism, we hypothesize that RM will be less useful if customers' demand or purchasing task is simple with cognitive resources are fully prepared. In contrast, recommendations can be more helpful if customers' needs are complicated and lack of cognitive resources. RMs can be very useful if they provide right information that properly fits customers' needs. Drawing on the resource matching theory, we develop our research model and hypotheses in the following.

## **MODEL AND HYPOTHESES**

### ***Independent Variable: Personalization on E-Commerce***

As the amount of e-commerce websites grows, customers may have trouble selecting products and leads to unpleasant shopping experience. Personalized services not only reduce customers' shopping costs but also consolidate vendor-buyer relationship. Personalization has been a buzzword word in e-commerce for years and recognized as an important approach in maintaining customer relationship (Fan & Poole, 2006). Personalization is defined as a process that changes the functionality, interface, information access and content, or distinctiveness of a system to increase its personal relevance to an individual or a category of individuals (Fan & Poole, 2006). Perceived personalization will affect a customer's beliefs about recommendation mechanisms (Komiak & Benbasat, 2006). Personalization levels is regarded as the degree personalized offers provided to customers, and it can be categorized into three levels: one-to-all, one-to-many and one-to-one (Forrester Research, 2007, p. 2).

One-to-all: General, standardized offerings. Every customers receive the same recommended content.

One-to-many: Segmental, partial personalized offerings. A cluster customers with similar preferences are categorize into a sub-group. The One-to-many recommendation contents are provided to each sub-group with similar preferences in accordance with that specific group's features.

One-to-one: highly personalized recommendation. Every customer receives different personalized recommendation based on one's characteristics.

According to Xiao and Benbasat (2007), recommendation mechanisms (RMs) are software agents that elicit interests or preferences of individual users for products, either explicitly or implicitly, and make recommendations accordingly. RMs services are becoming more and more common in e-commerce websites providing personalized services to customers for finding suitable products, reducing information overload, and facilitating their decision-making (Lee & Kwon, 2007). Research also found that offering RMs can

improve customers' decision quality (Lee & Kwon, 2007). The real RM examples corresponding to each personalization level are listed in Table 1.

**Table 6.** Examples of RMs

Personalization Levels	RM Examples
One-to-All	Trending in category
	Site top sellers
One-to-Many	Visitors who viewed this products also viewed
	Visitors who viewed this products ultimately bought
	Customers also bought
	Customers who bought this products also bought
One-to-One	You might also like
	Recently viewed
	Items viewed with items in your cart
	Top sellers from your recent categories on homepage

Source: MarketingSherpa

**Dependent Variable: Perceived Usefulness**

Perceived usefulness is defined as “the degree to which a person believes that using a particular system would enhance his or her job performance” (Davis, 1989). According to Xiao and Benbasat (2007), perceived usefulness on recommendation is the user’s perceptions of the utility of RM content. A different level of personalization may lead customers perceive different usefulness (Komiak & Benbasat, 2006). Therefore, we hypothesize

**H1:** Different RMs with different levels of personalization level have different perceived usefulness.

**Moderating Variable: Complexity**

According to RMT, the more complicated information customers need to process, the more cognitive resources they need. Previous research has investigated the influence of product attributes on information processing. For example, Bettman et al (1998) argues that the complexity of selecting a product under numerous product attributes is negatively affect customers’ decision making process. Studies conducted by Swaminathan (2003) and Xiao and Benbasat (2007) also show that product attributes can influence customers’ evaluation of RMs. In this study, we investigate how shopping complexity can influence perceived usefulness of RMs. Complexity in this research is defined as the numbers of the product attributes that are designated in purchasing processes. Two levels of complexity are manipulated: low versus high.

Low-complexity is operationalized as shopping with no attribute limitation; customers have more freedom as well as uncertainty on choosing products. Therefore, it is assumed that customers may receive much more irrelevant information to their preferences from RMs; information overload is more likely to happen when shopping under a no limitation condition. On the other hand, in a high complexity scenario, customers can filter product information using product attributes by themselves first, and may be surround with less unrelated information. Therefore, we hypothesize that customers may feel RMs more useful under a low complexity scenario given that RMs could reduce information overload and increase product choosing effectiveness.

**H2a:** Low task complexity enhances RMs’ perceived usefulness.

However, it is also possible that in a high complexity scenario, RMs could be more useful since RMs can capture more product attributes and then precisely recommend products or information that fit customers’ preferences. Therefore, a competing hypothesis is also proposed in the following. We will examine the two competing hypotheses by our data.

**H2b:** High task complexity enhances RMs' perceived usefulness.

***Moderating Variable: Familiarity***

To balance cognitive resources and task demands, customers first search for internal resources for decision-making. Based on RMT, internal resource is defined as customers' understanding of an entity (product) which is related to their previous interactions, experience, and learning of "the what, who, how, and when of what is happening" (Gefen, Karahanna, & Straub, 2003). Familiarity is another term highly related to internal resources used in RMT. Familiarity is relevant to customers' previous product search/buying experience. Therefore, we define customers' familiarity with a product as internal resources in this study.

Familiarity may influence consumers' feeling when surfing products online, which reflects direct and indirect knowledge available to the individual (Alba & Hutchinson, 1987). Park and Lessig (1981) shows that familiarity may lead to different information processing activities. We thus refer users with high familiarity of products as experts since they have more experience and knowledge. Chi et al (1979) indicates that customers who are experts can interpret problem attributes, activate related category and construct for solutions with available knowledge associated with the category. Kline and Wagner (1994) shows that users with high category knowledge are more likely to refer to internal information and be more reliant on their own knowledge. In this study, we aim to investigate how users with different levels of familiarity perceive usefulness of different RMs. Two levels of familiarity are manipulated: low versus high. We first measure a user's level of product familiarity by asking whether he/she has purchased/intensively search for the same products in the past three months. Subjects who have surfed category-related information are likely to have more information (internal resources) to the products and deemed as high familiarity users to that category. This type of users tend to rely on their own knowledge rather than RMs' recommendation whereas users who are not familiar with the products may feel RMs' recommendation more useful. We thus hypothesize:

**H3:** Low familiarity enhances RM's perceived usefulness (the less familiar the customers are with the product, the more useful the RMs will be).

***Moderating Variable: External Information***

Customers' internal resources are limited; therefore, they seek for additional external (or online) resources when necessary. The external information distinguishes from internal resources since it helps customers to equip more cognitive resources while dealing with purchase decisions. On the other hand, if cognitive resources are sufficient for decision-making, the probability of soliciting information from additional resources decreases. Interestingly, if searching for external information (e.g. Google search) is not available or allowed for a customer during purchasing, it could enhance customers' perceived usefulness of RMs. Thus, two scenarios related to searching for external information are investigated: low external information (not allowed for external searching) versus high external information (allowed). We propose that:

**H4:** Low external information acquirement increases RM's perceived usefulness (the less external information the customers have, the more useful the RMs will be).

Our proposed model and hypotheses are shown in Figure 1.

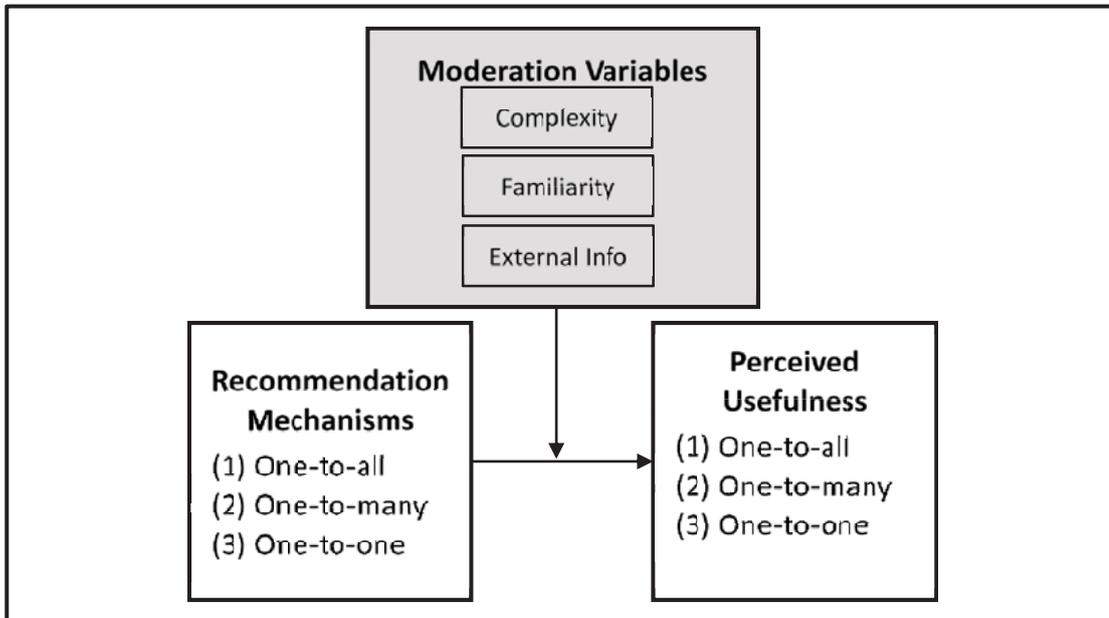


Figure1. Research Model

## METHODOLOGY

### Experiment Design

To examine how the perceived usefulness vary with different recommendation mechanisms in different scenarios, we conducted an experiment on an existing e-commerce website, Yahoo! Buy (<https://tw.buy.yahoo.com/>). Yahoo! Buy is one of the most popular B2C e-commerce website in Taiwan, which provides many kinds of recommendation mechanisms including the three levels of personalized RMs we mentioned above.

A total of 268 participants joined the experiment. Fifty-five percent of them were female; 43 percent of them were heavy internet user (i.e. using internet browsing over four hours per day). Through a pre-experimental questionnaire, we ensured that all the participants had the experiences of shopping online recently (within three months). Participant were debriefed about the research purpose and experiment procedures.

Table 7. Participant Descriptive Statistics

Demographics		Count	Percentage (%)
Gender	Male	121	45.1
	Female	147	54.9
Age	15-24	215	80.2
	25-34	39	14.6
	Others	14	5.2
Occupation	Student	230	85.8
	Others	19	7.1
	IT	11	4.1
	Retailing	3	1.1
	Manufacturing	3	1.1
	Government	2	0.7
Time spend online (hrs./day)	< 1 hr.	3	1.1
	1-3 hrs.	59	22.0
	4-7 hrs.	127	47.4
	8-11 hrs.	48	17.9
	> 12 hrs.	22	8.2

### Construct Operationalization

The three personalized RMs used in this experiment are one-to-one, one-to-many-and one-to-one. We used the existing mechanisms on Yahoo! Buy to operationalize the three different personalized RM:

**One-to-All: “Leaderboard”, [LB]**

[LB] is the mechanism that shows the bestselling products on the Yahoo! Buy website. The content and display of [LB] is according to sales ranking in each of the product category.

**One-to-Many: “Customers Who Bought This Item Also Bought...”, [Also]**

[Also] mechanism recommend other products purchased by those customers who bought the same product as the focal customers do. The recommended products are generated by affinity analysis from consumers buying data.

**One-to-One: “Items You Probably Looking For...”, [Prob]**

[Prob] provides highly customized recommendation lists. The content recommended are generated from personal, historical data including products, brands, stores, and artificial intelligence is used in the recommended processes.

**Table 8.** Used RM in This Study

Personalization levels	Used RM in this study
One-to-All	Leaderboard [LB]
One-to-Many	Customers Who Bought This Item Also Bought... [Also]
One-to-One	Items You Probably Looking For... [Prob]

**Perceived Usefulness:**

Measurements of perceived usefulness were adapted from Davis’s TAM scale (Davis, 1989), and all the measurement items are use a five-point Likert scale, ranging from strongly disagree (1) to strongly agree (5).

**Complexity:**

Complexity is operationalized by the number of product attributes during the experiment process. Participants who are assigned to low complexity scenario only have to select the assigned product they like (i.e. no product attributes required). In contrast, participants who are assigned in high-complexity scenario have to choose products under requested product attributes. For instance, participants who were assigned to buy clothing have to choose the cloth he/she might wear to a wedding party and price under US\$ 200; laptop buyers have to pick a laptop with the highest price–performance ratio and price under US\$ 1000.

**Familiarity:**

We manipulate familiarity by asking participants “What products have you searched/purchased on e-commerce websites in the past 3 months?” in a pre-experimental questionnaire. Doing so, we can see what products that participants are familiar with, and then designate participants to a low- or high- familiarity scenarios accordingly.

Two products are investigated in this study: clothing and laptop. Participants who are assigned to low familiarity scenario have to buy a product that he/she was not familiar with. For example, if a participant has searched clothing within past 3 months, then he/she was assigned to buy a laptop in a low-familiarity condition. In contrast, participants who were assigned to high familiarity condition have to purchase products that they familiar with.

**External Information:**

Two conditions was manipulated: allowed to and not allowed to search other websites (such as Google) when purchasing products. Participants who were allowed to search other websites can browse product reviews or articles and gather more information before making a decision. Participants who were not allowed to access other information can only browse product information on Yahoo! Buy.

**Table 9.** Manipulations of the three variables.

	H	L
<b>Complexity</b>	To select a product under attribute restrictions	To select a product with no attribute restrictions
<b>Familiarity</b>	To select a product in a familiar category	To select a product in an unfamiliar category
<b>External Information</b>	Allowed to access other websites	Not allowed to access other websites

**Experiment Procedures**

Each participant was assigned to a scenario that was stipulated by the combination of the three variables above. Participants were asked to evaluate perceived usefulness of recommendation mechanisms (RMs). Filling out a pre-experimental questionnaire and a post-experimental questionnaire was required by every participants. The procedure of the experiment is as following:

**Pre-Experimental Questionnaire**

The pre-experimental questionnaire aims to comprehend the understanding of participants to each mechanism based on their previous experiences, while measure their familiarity of products.

**Experiment: Shop at Yahoo! Buy under assigned scenario**

Each participant was assigned to a shopping scenario at Yahoo! Buy. Given that we manipulate three variables (complexity, familiarity, external information), and each has two levels (high and low), we have eight scenarios in total. The number of participants in each scenario is listed in Table 5. Furthermore, there are two products (laptop and clothing) investigated in the study, and each participant was assigned to a specific product category by the pre-experimental questionnaire. The two products are different in nature: clothing is more reliant on personal preference while laptop focuses more on physical features of the specifications.

**Table 10.** Scenario Combinations

Scenario	A	B	C	D	E	F	G	H
Familiarity	H	H	L	L	H	H	L	L
External Information	H	L	H	L	H	L	H	L
Complexity	H	H	H	H	L	L	L	L
Number of subjects	40	34	37	30	31	31	33	32

(H: High; L: Low)

**Post-Experimental Questionnaire**

Both the pre-experimental and post-experimental questionnaires ask participants to evaluate their perceived usefulness of RMs. The difference between the two questionnaires is that in the pre-experimental questionnaire, respondents answer the perceived usefulness of each RM based on their general feelings (past experience), while in the post-experimental questionnaire, each participant has to fill out the questionnaire based on the experiment they just did under a designated scenario.

**DATA ANALYSIS AND RESULTS****Pre-Experiment vs. Post-Experiment**

We conducted a paired T-test to check our manipulation effect. The T-test results show that the manipulation in the experiment on perceived usefulness of RMs has a significant difference ( $p=0.000$ ) before and after the experiment. In other words, users under different scenarios that we manipulated would change how they perceive usefulness of RMs. Therefore, understanding how participants perceive the usefulness of RMs under

different scenarios should have many managerial insights for e-commerce vendors. The T-test result is shown in Table 6.

**Table 11.** T-test

		Mean	SD	T	DF	Sig.
Paired	Pre-Exp PU	2.98	1.27	-7.533	512	.000
	Post-Exp PU	3.45	0.62			

Note: (“Pre-Exp PU” and “Post-Exp PU” as the perceived usefulness tested before and after the experiment stage respectively.)

To further understand how the participants change their perceived usefulness of the three RMs, we conducted ANOVA to test whether customers’ perceived different usefulness among the three RMs before and after the experiment. First, the descriptive statistics and the ANOVA test of the perceived usefulness evaluated at pre-experiment stage is reported in Table 7. The overall perceived usefulness of each RM does not show a significant difference before the experiment. That is, customers do not see any differences among the three RMs based on their previous shopping experiences.

**Table 12.** Pre-Experiment Significance to RMs

RMs	Pre-Experiment	Sig.
[LB]	3.34	0.100
[Also]	3.46	
[Prob]	3.36	

However, the post-experiment ANOVA test (Table 8) shows that participants perceive significantly different usefulness of the three RMs after conducting a purchasing task on a given scenario. According to the post-experimental results, one-to-many mechanism [Also], provides the highest usefulness (Mean=3.64), followed by [LB] (Mean=3.44) and [Prob] (Mean=3.24). H1 is supported by our manipulation.

**Table 13.** Post-Experiment Significance to RMs

RMs	Post-Experiment	Sig.
[LB]	3.44	0.000
[Also]	3.64	
[Prob]	3.24	

**Moderation Effects**

Hypothesis H2a proposes that RMs can be more useful if the complexity of selecting a product is low. The results in Table 9 show that in low-complexity scenario, no significant difference are found in all of the three RMs. Participants do not perceive the three RMs differently before and after the experiment. However, for those high complexity tasks, a significant difference of perceived usefulness was found in [Also] mechanism (p=0.018, Δ perceived usefulness of Also=3.69-3.46= 0.23). Customers perceived a significant enhancement of the usefulness from the one-to-many [Also] recommendation when they have to select a product with restrictions. Thus, between the two competing hypotheses, H2a is not supported while H2b is partially supported.

**Table 14.** The Moderation Effect of Complexity to Each RM

	Complexity			
	L	Sig.	H	Sig.
Pre [LB]	3.42	0.533	3.24	0.127
Post [LB]	3.49		3.37	
Pre [Also]	3.54	0.539	3.46	0.018
Post [Also]	3.61		3.69	
Pre [Prob]	3.25	0.636	3.36	0.106
Post [Prob]	3.31		3.18	

In the manipulation of familiarity (Table 10), significant differences of perceived usefulness were found in [LB] and [Prob] mechanisms under low familiarity condition ( $p$  of [LB]=0.000,  $\Delta$ LB=3.66-3.30=0.33;  $p$  of [Prob]=0.000,  $\Delta$ Prob=2.71-3.38= -0.67). However, the significance shown in the two scenarios are different.

First, customers tend to refer to best-selling products [LB] when they select unfamiliar products. We can found that perceived usefulness of [LB] after the experiment (low familiarity scenario) is significantly higher than that before the experiment. Secondly and to our surprise, the perceived usefulness of [Prob] after the experiment dropped significantly. The results imply that customers perceived less usefulness for those highly personalized RM ([Prob]) when they have to choose an unfamiliar product. Hypothesis H3 proposes that customer feel higher usefulness when they select product in an unfamiliar category; thus, H3 is partially supported. In an unfamiliar product purchasing scenario, customers prefer a more general recommendation mechanism ([LB]), whereas a more personalized mechanism ([Prob]) is not welcomed by customers. Interestingly, in a high familiarity scenario, since customers are familiar with the product, they prefer more a personalized recommendation mechanism [Prob] ( $p = 0.000$ ,  $\Delta$ [Prob]=3.72-3.25= 0.47)

**Table 15.** The Moderation Effect of Familiarity to Each RM

	Familiarity			
	L	Sig.	H	Sig.
Pre [LB]	3.30	0.000	3.32	0.125
Post [LB]	3.66		3.15	
Pre [Also]	3.57	0.133	3.43	0.115
Post [Also]	3.72		3.59	
Pre [Prob]	3.38	0.000	3.25	0.000
Post [Prob]	2.71		3.72	

Hypothesis H4 proposes that the usefulness of RM increases if the search for external information is prohibited. According to the result (Table 11), H4 is partially supported; the perceived usefulness of [Also] increases significantly if external information is prohibited ( $p$  of [Also]=0.001,  $\Delta$  [Also]=3.78-3.48=0.3). On the other hand, if customers are allowed to search for external information, the usefulness of [LB] increases ( $p$  of [LB]=0.043,  $\Delta$  [LB]=3.46-3.25=0.21). When ranking information is provided, customers refer to [LB] recommendations and collect comparative information of the product items.

**Table 16.** The Moderation Effect of External Information to Each RM

	External Info			
	L	Sig.	H	Sig.
Pre [LB]	3.38	1.000	3.25	0.043
Post [LB]	3.38		3.46	
Pre [Also]	3.48	0.001	3.51	0.882
Post [Also]	3.78		3.53	
Pre [Prob]	3.29	0.893	3.33	0.115
Post [Prob]	3.40		3.16	

**Sample Splitting**

We further investigate the effectiveness of the three moderators by separating our data into two categories: laptop buyers and clothing buyers. Also, we compare the perceived usefulness of the three RMs after the experiment (i.e. post-experiment usefulness).

**Laptop buyers**

(1) Complexity

In the low complexity scenario (purchasing under no product attribute requirement, second column of Table 12), customers perceive significant different usefulness among the three RMs, with [Also] mechanism

received the highest perceived usefulness. Under the high complexity scenario (third column of Table 12), [Also] once again is perceived as the most useful mechanism.

Interestingly, only [Also] mechanism shows a significant difference on the two complexity level (fourth row,  $p$  [Also]=0.074, Low-complexity: Mean=3.60, High-complexity: Mean=3.79). Customers perceived extremely high usefulness of the [Also] mechanism when purchase more complex product with more attributes requirement. On the other hand, a more personalized recommendation [Prob] is not suitable for a high restriction condition (Mean=2.95, lowest in the six cells). One reason might be that the high complexity condition is more like a goal-directed task. If the personalized recommendation doesn't fit the restrictions, the usefulness of recommendation reduces.

**Table 17.** The Moderation Effect of Complexity for Laptop buyers

Complexity			
	L	H	Sig.
Post [LB]	3.57	3.52	0.709
Post [Also]	3.60	3.79	0.074
Post [Prob]	3.15	2.95	0.112
Sig.	0.001	0.000	

(2) Familiarity

The third row and the fifth row in Table 13 show that when we manipulate different level of familiarity, customers perceive significantly different usefulness of the two RM: [LB] and [Prob] ( $p$  [LB]=0.000,  $p$  [Prob]=0.000). The usefulness of [LB] decreases when customers are familiar with the product (Low-familiarity: Mean=3.75; High-familiarity: Mean=3.03). As discussed earlier, when customers are more familiar with the product, and have high category knowledge of the product, they tend to rely on their internal resources more. They perceive more usefulness of leader board when they are familiar with the products.

On the other hand, the perceived usefulness of the more personalized mechanism [Prob] increases when customers are familiar with the products. High-familiarity can results in more suitable recommendations of [Prob] (Low-familiarity: Mean=2.79, High-familiarity: Mean=3.58). Customers have high-familiarity with the purchasing products prefer more personalized recommendation mechanism [Prob], rather than the more general recommendation [LB]. H3 is partially supported.

**Table 18.** The Moderation Effect of Familiarity for Laptop buyers

Familiarity			
	L	H	Sig.
Post [LB]	3.75	3.03	0.000
Post [Also]	3.76	3.62	0.182
Post [Prob]	2.79	3.58	0.000
Sig.	0.000	0.000	

(3) External Information

Forth row of Table 14 shows that the manipulation of external information has impacts on the perceived usefulness of the RM [Also] in the two different levels ( $p$  [Also]=0.075). Allowing to search for external information (High external information) reduce the usefulness of [Also]. However, it is noted that [Also] has the highest perceived usefulness in both low- and high- external information conditions (Low-external information: Mean=3.81, High-external information: Mean=3.63). Thus, our hypothesis H4 is partially supported.

**Table 19.** The Moderation Effect of External Information for Laptop buyers

External Information			
	L	H	Sig.
Post [LB]	3.58	3.51	0.571
Post [Also]	3.81	3.63	0.075
Post [Prob]	3.06	3.01	0.707
Sig.	0.000	0.000	

### Clothing Buyers

#### (1) Complexity

Different levels of complexity do not show any significant impact on the usefulness of each RM ( $p$  [LB]=0.348,  $p$  [Also]=0.580,  $p$  [Prob] =0.806). That means the perceived usefulness of each RM is not influenced by the restrictions when selecting clothing. Thus, H2 is not supported for clothing buyers. This is a different results from that in buying laptops.

On average, [Also] is perceived as the most useful RM, while [LB] is evaluated as the least useful one. As ANOVA results shown (second and third columns), when buying clothing with low complexity, customers do not perceive difference within the three RMs whereas clothing buyers assigned to a high complexity scenario (purchasing with attribute restriction) perceived a significant difference among the three RMs ( $p$  H-com=0.093). In other words, when customers have to select clothing with restrictions, they perceive [Also] as the most useful recommendation and [LB] the least useful one.

**Table 20.** The Moderation Effect of Complexity for Clothing buyers

Complexity			
	L	H	Sig.
Post [LB]	3.41	3.26	0.348
Post [Also]	3.60	3.54	0.580
Post [Prob]	3.44	3.40	0.806
Sig.	0.357	0.093	

#### (2) Familiarity

As shown in Table 16, in the manipulation of familiarity, the perceived usefulness of [LB] and [Prob] are significantly different under different levels of familiarity ( $p$  [LB]=0.036,  $p$  [Prob]=0.000). When buying clothing, customers perceive lower usefulness of [LB] under high familiarity scenario (Low familiarity: Mean=3.52, High familiarity: Mean=3.19). In contrast, customers prefer a more personalized RM [Prob] when buying clothing in a high familiarity scenario (Low familiarity: Mean=2.69, High familiarity: Mean=3.76). The results imply that those customers with a high familiarity to clothing prefer the effectiveness of a personalized recommendation. The second column and third column also show that the difference among the three RMs was also significant in both the high and low familiarity scenarios ( $p$  L-fam=0.000,  $p$  H-fam=0.000).

**Table 21.** The Moderation Effect of Familiarity for Clothing buyers

Familiarity			
	L	H	Sig.
Post [LB]	3.52	3.19	0.036
Post [Also]	3.58	3.56	0.839
Post [Prob]	2.69	3.76	0.000
Sig.	0.000	0.000	

#### (3) External Information

The fourth and fifth row in Table 17 show that allowing to search for additional information or not significantly influence the usefulness of [Also] and [Prob] ( $p$  [Also]=0.001,  $p$  [Prob]=0.05). For the [Also] mechanism, customers feel [Also] mechanism is much more useful when not allowing to search for external information (Low external information: Mean=3.75, High external information: Mean=3.40). Similarly, [Prob] mechanism also is felt much more useful when not allowing to search for external information (Low external information: Mean=3.55, High external information: Mean=3.28).

On the other hand, the second column of Table 17 shows that when customers are not allowed for external searching, they feel significantly different on the usefulness of the three RMs ( $p = 0.001$ ), with [Also] is felt as the most useful RM (Mean=3.75). When customers are allowed for external searching, there is no difference among the usefulness of the three RMs.

**Table 22.** The Moderation Effect of External Information for Clothing buyers

External Information			
	L	H	Sig.
Post [LB]	3.25	3.40	0.320
Post [Also]	3.75	3.40	0.001
Post [Prob]	3.55	3.28	0.050
Sig.	0.001	0.623	

**Combination of Multiple Variables**

Table 18 shows the results of combing all the three moderators and comparing the eight scenarios together. Among the eight scenarios, there are four scenarios in which customers perceive the [Also] mechanism the highest usefulness, three from the [Prob] mechanism, and only one from the [LB] mechanism. Therefore, though [LB] is a very common RM on e-commerce websites, overall speaking, customers do not feel strong usefulness from the content it provide. It seems that customers prefer more personalized RMs that filter information and narrow down choices.

However, if we do a sample split by separating clothing buyers and laptop buyers, the results show a different story. Laptop buyers tend to seek for related product information by preferring the [Also] mechanism, which provides the preferences of customers alike. There are five out of the eight scenarios in which that laptop buyers prefer the [Also] mechanism. It implies that laptop buyers prefer more related information, which helps them to collect more cognitive resources of product attributes then select products.

On the other hand, clothing buyers tend to do more window shopping, select products without gathering more information, and rely on their own judgement. Their preferred RMs are more evenly distributed among the eight scenarios. Clothing buyers in high familiarity scenarios perceived usefulness on [Prob]. Recommendation content from [Prob] on clothing is more likely to be close to customers’ choices when they shop clothing frequently.

**Table 23.** Influence of Multiple Variables

Overall								
	A	B	C	D	E	F	G	H
[LB]	3.15	3.08	3.58	3.72	3.25	3.07	<b>3.82</b>	3.61
[Also]	3.41	<b>3.87</b>	<b>3.72</b>	<b>3.81</b>	3.24	3.79	3.64	<b>3.62</b>
[Prob]	<b>3.69</b>	3.67	2.67	2.68	<b>3.62</b>	<b>3.83</b>	2.84	2.95
Laptop								
	A	B	C	D	E	F	G	H
[LB]	3.05	2.94	3.81	3.75	2.79	3.33	<b>3.79</b>	<b>3.68</b>
[Also]	3.54	<b>3.94</b>	<b>3.84</b>	<b>3.89</b>	<b>3.00</b>	<b>3.86</b>	3.64	3.61
[Prob]	<b>3.60</b>	3.43	2.71	2.63	<b>3.00</b>	3.81	2.98	2.90

Clothing								
	A	B	C	D	E	F	G	H
[LB]	3.26	3.13	3.22	<b>3.67</b>	3.40	2.97	<b>3.85</b>	3.48
[Also]	3.32	<b>3.84</b>	<b>3.46</b>	3.61	3.33	3.75	3.64	<b>3.64</b>
[Prob]	<b>3.73</b>	3.73	2.61	2.42	<b>3.76</b>	<b>3.83</b>	2.65	3.03

Note: the highest numbers in each column is highlighted in bold.

## DISCUSSION AND CONCLUSION

As theorized in the resource matching theory, we exam customers’ perceived usefulness toward the existing three personalized recommendation mechanisms (RMs) by manipulating the shopping scenarios customers might face. E-commerce vendors would eagerly know what kind of recommendation mechanisms customers need the most when shopping in different scenarios. As the results showed in the last section, customers like the partial personalized recommendation mechanism [Also] most of the time.

However, the usefulness of recommendation mechanism might be influenced by some moderating factors. We thus conducted the experiment by manipulating the scenarios that customers might encounter to find the best-fit recommendations. We summarize our interesting findings in the following:

When customers buy unfamiliar products, the usefulness of highly personalized recommendation decreases and that information could be regarded as irrelevant recommendation. Low familiarity customers seek for less personalized content. On the other hand, customers with high familiarity tend to rely on self-recognition. They are less likely to use best-selling products [LB] mechanism since they already have their judgments in mind. Therefore, if e-commerce vendors found that a customer lack of historical data in a specific product category, and could have a higher chance of unfamiliarity, we recommend e-commerce vendors to offer more non-personalized recommendations for customers.

We also found an interesting result that customers have different attitude toward [LB] and [Prob]. [LB] provides a more general content for all customers whereas [Prob] provides much more personalized content. Customers perceive reversed usefulness to the two RMs. We recommend e-commerce vendors to know customers better regarding their familiarity with the product, and to understand how complex the products that customers aim to purchase are, then provide suitable RMs so those recommended information do not provoke negative effects to customers.

Laptop buyers and clothing buyers tend to show different searching strategies. As mentioned above, there are two strategies in searching information: goal-driven and exploratory strategies. A laptop is an attribute-specific product whereas clothing is more based on individual preferences. We found that laptop users start their searching by filtering information using product attributes and narrow down product items. According to resource matching theory, filtering product information in a goal-driven purchasing task could reduce cognitive burden and accelerate decision-making effectiveness.

### Study Limitations and Further Research

We use Yahoo! Buy as our experiment environment to conduct a field study. The results we found may be influenced by other factors not controlled in the study such as interface design, web-site reputation, algorithms of RMs, and position where RM shows on a webpage. In a real shopping task, if customers are not willing to buy things at Yahoo! Buy, they can choose other e-commerce websites. Thus, we recommend future studies to include more e-commerce websites to compare the usefulness of different RMs.

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# Analysis of Employment Effects Resulting from Foreign Direct Investment

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## Abstract

With the development of China's reform policy, China's economy has integrating into the global economy. As a result, more and more foreign capital continues to flow into China. Since 1990, foreign direct investment (FDI) was mainly concentrated in the Yangtze River Delta region, and Shanghai enjoyed strong economic strength, thanks to its abundant human resources and convenient transportation network; as these are excellent qualities for attracting foreign investment, Shanghai became one of the major cities attracting FDI. FDI has had a tremendous impact on many aspects in Shanghai, including employment.

Therefore, Shanghai was chosen as the research object of this paper. This paper is organized as follows. Firstly, a theoretical analysis of the employment effects of FDI is presented. Secondly, after combining the actual utilization of FDI and employment in Shanghai, an empirical analysis of the effects of FDI on employment's quantity, employment's distribution and employment quality is carried out by collecting relevant data and establishing regression models. This study finds that while FDI does exert a positive influence on the quantity of employment in Shanghai's tertiary industry, it is not conducive to primary and secondary industries. In addition, FDI has shown positive and negative impacts on the quality of employment. Lastly, some suggestions are proposed to enhance the positive role of FDI on employment.

**Keywords:** Shanghai, FDI, Employment Effects, Employment Quantity, Employment Distribution, and Employment Quality

## 1. Introduction

In the last decade, China has grown rapidly because of FDI, and in 2002, China replaced the United States as the world's largest recipient of FDI. Shanghai is the metropolitan area of the Yangtze River Delta (YDA) and has exceptional conditions to attract foreign investment; therefore, Shanghai has turned into the major recipient of FDI in China.

The massive FDI inflows significantly affect Shanghai in many aspects, and employment is one of them. This research selects Shanghai as its subject and focuses on studying the effects of FDI on the "quantity of employment", "the employment distribution in three sectors of the economy", and "the effect on employment quality".

## 2. Analysis of the theory of FDI employment effect

### 2.1 Definition of FDI

"FDI" stands for "Direct International Investment", also known as "Foreign Direct Investment", which means investors participate in the entity's production and operation, and exercise substantial control over management. The yield relies on the condition of the entity's operation and exhibits high variability.

### 2.2 Analysis of the Theories on Employment Effects from FDI

Among contemporary studies, most of the scholars suggest that the employment effects caused by FDI in the host countries are

mainly on three aspects: quantity of employment, employment distribution in the three sectors of the economy as well as quality of employment.

### (1) Effects on Quantity of Employment

Yu Mai Tang (2008) believes that FDI causes both positive effects and negative impact on the quantity of employment in the host countries: FDI will increase job opportunities, which is a positive employment-generation effect, but in the other hand, the international enterprises' entering will cut some existing employees, causing a negative crowding-out effect.

### (2) Effect on Employment Generation

“Effect on Employment-Generation” means the FDI will create considerable job opportunities and boost employment. Generally speaking, the effects on employment by FDI are “Direct Generation Effect” and “Indirect Generation Effect”.

#### A. Direct Generation Effect

“Direct Generation Effect” means the FDI creates job opportunities and increases employment directly in the host country. When an international company enters with “Greenfield Investment”, it will bring net capital into the host country. The international company will establish subsidiaries or an operation base there. The newly-founded company will recruit local people and increase employment in the host country.

#### B. Indirect Generation Effect

“Indirect Generation Effect” means the job opportunities in host countries are increased with other approaches.

Firstly, the FDI will form an “enterprise-correlation effect” by increasing the job opportunities in local companies which associate with the inter-country companies. The entering of the FDI's companies will drive the operation of the local companies. When the demand of the foreign companies is equal to the domestic companies' output, the demand of the products will rise, and then the local companies' scale of production will be expanded. The labor demand of domestic companies will have a surplus due to the shortage of employees, and then the domestic companies will have to recruit new employees in order to increase productivity. Therefore new job opportunities will be generated indirectly.

Secondly, FDI will increase the quantity of employment indirectly by the “spillover effect”. Foreign companies often introduce new technologies and new types of industry into the host countries. Meanwhile, it will accelerate the development of the latest high-tech industry in the host countries and increase employment in multifarious industries. Therefore, numerous job opportunities will be generated indirectly. In addition, the FDI inflow brings capital which will rapidly spur productivity like the effect of economy of scale. As a result, the host countries' factors of production will be properly dispensed, and the not-utilized factors will be able to be utilized. The dominant resources can be employed efficiently to escalate new productivity and generate more new job opportunities.

### (3) Crowding-Out Effect

The “Crowding-Out Effect” often appears when an international company enters through “merger” or “acquisition”; as a result, a “reasonable” downsizing will occur, crowding out employees and cutting down employment. Moreover, the international companies usually have more strict criteria concerning employees' working skills than the local firms do; therefore it is a common phenomenon that local employees are laid off as a result of not meeting the skill requirements of the foreign companies. In addition, the foreign companies are more capital-intensive, so the operation mode should crowd out some employment in labor-intensive local companies. The entering of FDI will fuel the competition of the local market and eliminate the lame companies, thereby causing a considerable level of unemployment and reducing job opportunities.

#### (4) Effects from FDI on Employment Distribution in Three Sectors of the Economy

From an industrial perspective, the effects of FDI on the employment distribution in the three sectors will vary because of the different scope of influence from FDI in every sector.

##### A. Effects on Employment in the Primary Sector

Compared to other sectors, the impact from FDI on the primary sector is not great. The primary sector is mainly agriculture/farming and is usually run by “family”, so it does not require additional employees. Furthermore, as the agricultural industry of a country is vital for the citizens, the authorities will usually impose more restrictions on foreign entities wishing to engage in this field; as a result, foreign companies will make relatively low investment in this sector. In addition, related technologies are currently advancing at blinding speed. Since the agricultural industry also applies modern methods to production, this will lead to less demand on the labor force. As a consequence, the FDI certainly will not have any remarkable impact on the primary sector.

##### B. Effects on Employment in the Secondary Sector

In China, the secondary sector, mainly manufacturing, always plays the leading role in the national economy. FDI weighs heavily in this sector; therefore FDI has a more significant influence on employment in this sector.

##### C. Effects on Employment in the Tertiary Sector

In contemporary society, after material demands have been fulfilled, the demand for incorporeal service and spiritual satisfaction will be boosted, and it will lead the tertiary sector to blossom. Accordingly, foreign companies will keep increasing direct investment into the tertiary sector. The labor demand in the service industry is large, so FDI will surely have a greater scale of influence on employment in the tertiary sector.

#### (5) FDI Effects on the Quality of Employment

Regarding the quality of employment, FDI has both positive and negative effects.

##### A. Positive Effects

Cui, Xiaoning and Li, Zhi (2003) suggest that FDI can contribute to the improvement of employment quality in the host countries. Foreign companies often offer better wages, benefit packages and working environment; they also introduce new know-how and technologies to the employees in the host countries. Most of the foreign companies put a lot of effort into quality training, and enhancing workers' skills, so that after being recruited, employees have the opportunity to get training to improve various abilities. Meanwhile, the employees' quality and skills will be cultured and improved due to a superior working environment.

##### B. Negative Effects

The negative effects usually appear in regard to the foreign companies' negligence of employees in host countries. More and more foreign enterprises discriminate against the host country's social security system for the employees. That mainly happens in small-sized foreign companies, as some or all employees are unable to obtain basic social security services. To keep costs down, some foreign companies even provide very undesirable and poor working conditions with no security assurance, which raises considerable safety concerns about the working environment.

In conclusion, the analysis on the theory of employment quantity, employment distribution of the three sectors of the economy and employment quality reveals that FDI has both positive and negative effects. The following sections present research on FDI's

specific effects on the three aspects through empirical analysis.

### 3. Empirical Analysis of FDI's Effects on Employment: Shanghai

#### 3.1 FDI in Actual Use and Employment Performance in Shanghai

(1) FDI in actual use keeps expanding by year, with employment constantly climbing

Shanghai possesses leverages, such as plentiful information flow, logistics support and a mature financial market, to attract numerous international companies. According to the statistics, Shanghai has become the most preferred city for FDI in China. The FDI started to flow into China in 1979, but did not reach the Yangtze River Delta region until 1986. Therefore, this study adopted the statistics after 1986. Despite a few years during which actual FDI inflow, dropped, as Fig. 1 illustrates, the trend of foreign investment in actual use went up by year, and in employment grew constantly in Shanghai between 1986 and 2008.

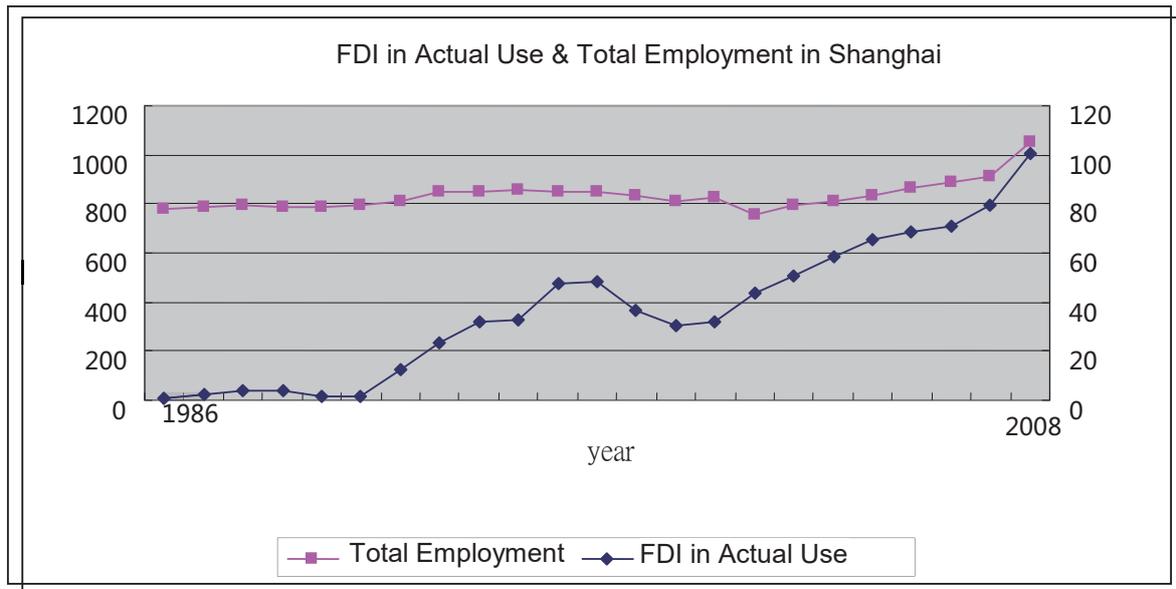


Fig. 1: FDI in Actual Use & Total Employment in Shanghai

This study is based on the “Analysis of FDI’s Development in China- by Stages” (Cao, Hungyu) and the development of FDI is divided into four stages in order to portray how Shanghai dealt with FDI as well as the condition of employment.

1st Stage, Beginning Stage (1986-1991): China’s open policy focused on the southern regions of Shenzhen, Guangzhou (Pearl River Delta Region) and Xiamen, and foreign companies were set up there in this stage. So Shanghai had very little FDI in actual use, and employment experienced no apparent fluctuation. Employment was basically maintained at approximately 8 million.

2nd Stage, Stage of Skyrocketing (1992-1997): FDI in actual use reached a climax in Shanghai in this stage. In 1992, the FDI in actual use in Shanghai was US\$1.3 billion, exceeded US\$2.3 billion in 1993, US\$3.2 billion in 1994, US\$4.7 billion in 1996, and US\$ 4.8 billion in 1997. Meanwhile, total employment remained at a relatively stable state. The total employment in Shanghai was 8.069 million people in 1992, and surged to 8.5 million in 1997.

3rd Stage, Stage of Adjustment and Shrinking (1998-1999): Due to the Asian financial crisis in 1997, the FDI in actual use showed a negative growth in Shanghai. The growth rate was -24.3% in 1998, and -16.4% in 1999. Employment also had negative growth rate in this phase: -1.3% in 1998 and -2.9% in 1999.

4th Stage, Stage of Sustained Growth (2000-2008): FDI in actual use surged yearly in this stage. FDI in actual use in Shanghai was

US\$3.16 billion in 2000, US\$4.392 billion in 2001, over US\$5 billion in 2002, and over US\$10 billion in 2008. In this phase, employment in Shanghai also showed a surging trend. By 2008, total employment in Shanghai reached 10.5324 million people.

(2) FDI mainly pooled in the tertiary sector of the economy, followed by the secondary, and was least in the primary sector

According to the latest statistics, the actual FDI inflow to tertiary sector in Shanghai was US\$6.835 billion in 2008, which was 67.78% of the total actual FDI inflow for the entire year. In the mean period, it was US\$3.263 billion for the secondary sector, which was 32.09% of the total, while the primary sector gained US\$13 million from FDI, which was a paltry 0.13% of the total. It is pretty clear that the tertiary sector had attracted far more foreign capital than the secondary or primary sector did in Shanghai.

The figures show that the amount of FDI flowing into secondary sector surpassed that in the tertiary sector. Fig. 2 reflects the real state of actual FDI inflow to the three sectors in Shanghai between 1999 and 2008.

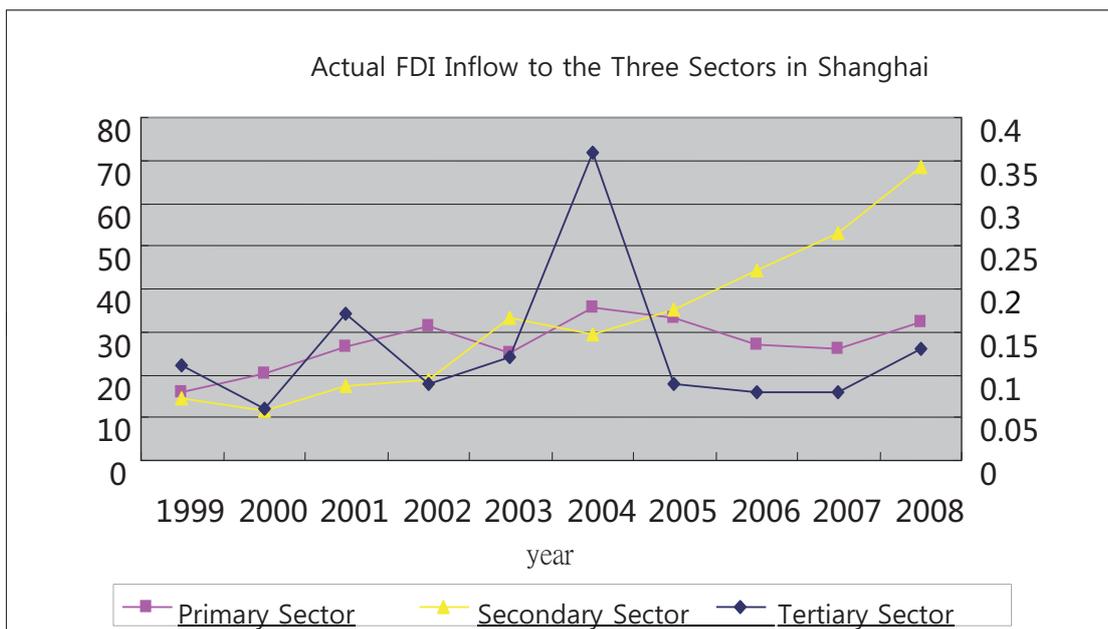


Fig. 2: Actual FDI Inflow to the Three Sectors in Shanghai between 1999 and 2008

- Actual FDI Inflow to the Three Sectors in Shanghai
- Actual FDI Inflow to the Secondary & Tertiary Sector (per US\$100M)
- Actual FDI Inflow to the Primary Sector (per US\$100M)
- Actual FDI Inflow to the Secondary Sector
- Actual FDI Inflow to the Tertiary Sector
- Actual FDI Inflow to the Primary Sector

Fig. 2 illustrates that the primary sector’s FDI always remained at the lowest level. The bottom point was merely US\$6 million in 2000, and the peak was US\$17 million in 2001. Regarding the secondary sector, the actual FDI inflow showed the trend of up-surging between 1999 and 2000; it received the largest proportion of the total amount in this phase. In 1999, the secondary received US\$1.59 billion, and the tertiary sector took US\$1.54 billion. The greatest disparity happened in 2002, when the secondary sector gained US\$3.133 billion, and the tertiary sector merely acquired US\$1.888 billion. The gap was US\$1.25 billion during that period. Nevertheless the FDI flowing to the tertiary sector surpassed that to the secondary in 2003, and received the most from FDI. The trend of FDI flowing to the secondary sector kept descending starting from 2004. It was US\$3.587 billion in 2004 and was cut down to US\$2.597 billion in 2007. However, in the tertiary sector it was ascending: it was US\$3.337 billion in 2003 and hit US\$6.835

billion in 2008. The amount of FDI in the tertiary sector doubled within 5 years.

### (3) Tertiary Sector Becoming the Major Area of Employment

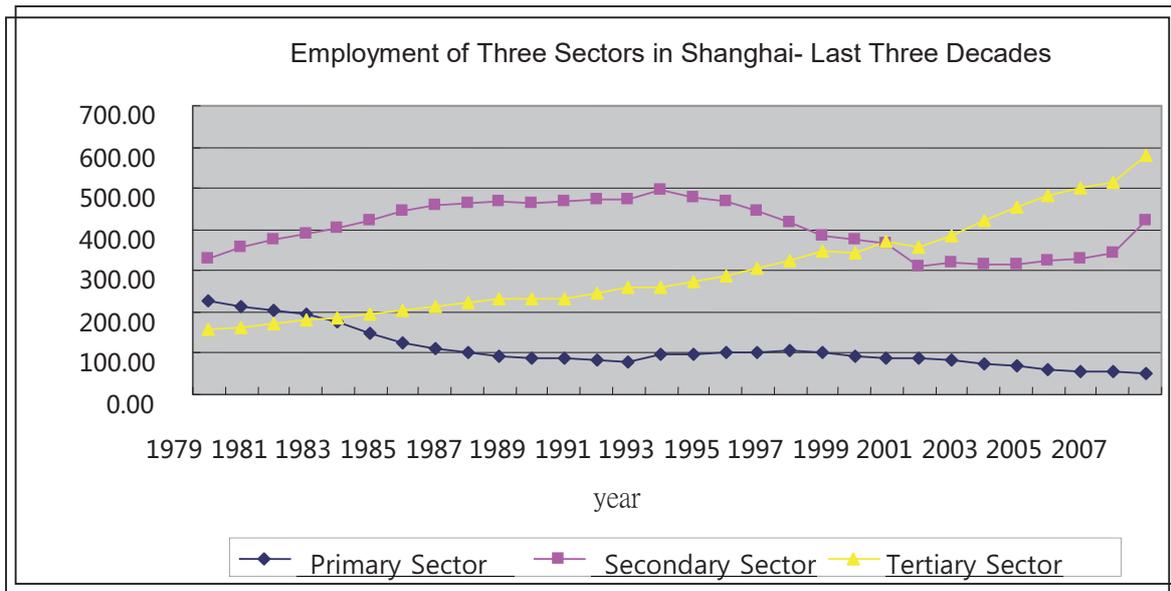


Fig. 3: Employment in the Three Sectors in Shanghai: Last Three Decades

Employment in the Three Sectors in Shanghai: Last Three Decades

Per 10K people

Employment in the Primary Sector

Employment in the Secondary Sector

Employment in the Tertiary Sector

Employment showed an obvious disparity among the three sectors in Shanghai. Before the 21st century, employment was clustered in the secondary sector, but since 2000, employment in the tertiary sector exceeded that of the secondary to become the major hiring industry. Fig. 3 illustrates employment in the three sectors in Shanghai during the past three decades.

In regard to the total employment figures in the three sectors, employment in the primary sector was 2.2485 million people in 1979 and then was reduced to 0.4938 million in 2008. The proportion shrank from 31.55% to 4.69%, a drop of 26.86 percentage points (pp) within 30 years. That implies that when the structure of a society moves towards industrialization and urbanization, a massive amount of surplus agricultural labor will transfer to the secondary and tertiary sectors. The proportion of secondary employment was expanding in Shanghai between 1979 and 1990. It was 46.43% in 1979 and reached 59.30% in 1990. Starting from 1991, the trend showed a decrease. It shrank from 59.04% in 1991 to 40.27% in 2008. The manufacturing industry was no longer an “accumulator” to increase employment. Employment in the tertiary sector kept expanding in Shanghai. It increased from 21.59% in 1978 to 55.04% in 2008; since 2000, the employment in the tertiary sector has exceeded that in the secondary sector.

### (4) The Ratio of Employment in Foreign Companies Rising by Year

The latest statistics indicate that the employees hired by foreign companies numbered 1.1337 million people in Shanghai in 2008, or 10.76% of the total employment, which was 10.5324 million people; in other words, out of every 100 employees, 10.5 worked for foreign companies.

Fig. 4 shows the statistics on the amount hired by foreign companies and the related information on total employment in Shanghai in the last 10 years.



Fig. 4: Amount Hired by Foreign Companies & Total Employment in Shanghai from 1999-2008

Amount Hired by Foreign Companies & Total Employment in Shanghai

Per 10K people

Year

Employment in Hong Kong, Macau, Taiwan & foreign companies

Total employment

Proportion of employment in foreign companies

Fig. 4 shows that hiring in foreign companies increased yearly in Shanghai between 1999 and 2008 except for 2008; the maximum amount was 1.2378 million people in 2007. In percentage terms, the employment in foreign companies in Shanghai was 0.568 million people in 1999, which was 6.24% of total employment and 8.08% in 2001, 10.04% in 2003, 10.41% in 2005 and 13.62% in 2007. The trend shows an yearly escalation trend, although the financial crisis in the second half of 2007 impacted employment in Shanghai. Hiring by the foreign companies was cut to 1.1138 million people in 2008, and the percentage dropped to 10.58%; however, employment in foreign enterprises increased overall, and the percentage compared to the total employment climbed steadily.

The analysis shows that the FDI in actual use in Shanghai kept growing every year, and that both total employment and employment in foreign companies were also increasing. With regard to the three sectors of the economy, FDI flooded into the tertiary sector, followed by the secondary, and the primary got the least. In conclusion, this research finds that FDI certainly affects the amount of employment and the employment distribution in the three sectors of the economy. The next section presents an empirical analysis on the effects to employment caused by FDI in Shanghai by establishing relevant models.

### 3.2 Empirical Analysis on Effects to Employment by FDI in Shanghai

#### (1) Effects on Quantity of Employment

According to the foresaid analysis, the FDI inflow will have a direct effect on the number of employed in the foreign companies

and indirect affect the total employment level in Shanghai. Therefore, an analysis of the effects on the quantity of employment by FDI in Shanghai follows, covering two aspects: the amount of hiring in foreign companies and the total amount of employment.

(2) Relevant Analysis on FDI and the Amount of Employment in Foreign Companies in Shanghai

A. Models and Variables

Most of the relevant studies suggest that the introduction of FDI will have a direct effect on the employment in the foreign companies, so we chose the “actual FDI inflow in Shanghai” as the independent variable and the amount of employment in foreign companies as dependent variable to establish the following model:

$$q_t = \beta_0 + \beta_1 fdi_t + \mu_t \tag{1}$$

The “q” stands for the “amount of employment in foreign companies in Shanghai”, and “fdi” stands for the “actual FDI inflow in Shanghai”. “ $\mu_t$ ” stands for random error, which reflects the uncertainties between “q” (“amount of employment in foreign companies”) and “fdi” (“actual FDI inflow”).

B. Model Operating and Output

We adopted the 1999 to 2008 period as the sample of the model. The relative figures are stated in the Table 2 in Appendix 1.

This section deals with the question: When the discrepancy of the relative figures is huge, will it seriously impact the regression results? Therefore, the currency of FDI value was converted from US\$100 million to RMB ¥ 100 million for the regression analysis. The “q” is the “amount of employment in foreign companies in Shanghai”, and the unit is “per 10 thousand people”.

The results from GLS (generalized least squares) regression analysis are as follows:

Table 1: Result of Regression of Amount of Employment in Foreign Companies

Variables/ Estimation	Coefficient	Sigma	T-value	P-value
c	13.64206	11.09792	1.229245	0.2539
fdi	0.146505	0.022548	6.497351	0.0002
R <sup>2</sup>	0.840687			
Adjusted R <sup>2</sup>	0.820773			
F value	42.21557			

The coefficient of determination R<sup>2</sup> in Table 1 is 0.841, which shows that the whole equation fitting is good. Under the condition that the significance level was preset at 5%, the F-number in the equation is larger than the critical number, 4.74, indicating that the result of the regression equation is significant. The t value corresponding to fdi is much greater than the critical number  $t_{0.025} (10-3) = 2.365$ , which shows that the fdi has a significant influence on the amount of employment in foreign companies.

The economic interpretation of the model is that for every RMB ¥ 100 million of FDI flowing into Shanghai, foreign companies will add 1470 employees.

(3) Analysis of the Relation between FDI and Total Employment

The aforesaid analysis of the theory has explicated that the FDI has both positive and negative effects on the amount of employment in the host country. In order to research the specific effects of FDI on the amount of employment in Shanghai. The following will

provide an analysis through the establishment of models.

#### A. Establishment of Models and Sample Statistics

Shanghai has recorded the relevant statistics on FDI since 1981, but the amount and scale of FDI was fairly small until 1992, so the time span of the statistics in this article is 17 years, between 1992 and 2008. Besides the factor of FDI, the research takes the wage issue into account as a fundamental factor affecting the amount of employment. Therefore the formation of the corresponding models is based on actual FDI inflow with wages as the explanatory variable, and the amount of employment in Shanghai as the response variable. The statistics on FDI deal with the amount of “foreign direct investment in actual use”, and the unit is 100 million. Wages are the total wages of employees in Shanghai in each corresponding year, and the unit is 100 million. Employment is the amount of total employment in Shanghai, and the unit is 10K people. The relevant figures are all from the “Shanghai Statistical Yearbook” and “China Financial Statistical Yearbook” in each corresponding year. The numbers are listed in the Table 1 of Appendix 1.

The model is as follows:

$$Q_t = \beta_0 + \beta_1 FDI_t + \beta_2 W_t + \mu_t \tag{2}$$

The “Q” stands for the total amount of employment in Shanghai. “FDI” is the “foreign direct investment” in Shanghai. “W” is the wages paid in Shanghai.

The regression analysis was used to analyze the model by Eviews 3.1 and obtain the results as listed in Table 2.

Table 2: Regression Result of Total Amount of Employment

Variable/ Estimation	Coefficient	Sigma	T-value	P-value
C	827.3756	33.58820	24.63292	0.0000
FDI	0.179268	0.063251	2.834249	0.0133
W	-0.121035	0.037216	-3.252226	0.0058
R <sup>2</sup>	0.640717			
Adjusted R <sup>2</sup>	0.599390			
F value	12.48327			

#### B. Model Checking

The above analysis shows that the coefficient of determination R<sup>2</sup> is 0.641, which indicates that the whole equation fitting is good. The degree of freedom is 14 and the critical number coefficient is: F<sub>0.05</sub> (2, 14) =3.74. The regression equation is: F > F<sub>0.05</sub>, which displays a significant linear relationship and shows that the explanatory variable and response variable are at high levels in regard to interpretation. When looking at t-value, under the condition that the significance level was preset at 5%, the critical number is t (17-3) =2.145 and the t-number corresponds to the FDI critical number of t, which shows that the FDI has a significant effect on the gross employment in Shanghai.

The economic interpretation of aforementioned model is that every \$100 million of actual FDI flowing into Shanghai will create 1790 job vacancies, which indicates that FDI will boost the growth of employment in Shanghai, a positive effect on the quantity of employment.

In conclusion, FDI inflow will definitely increase employment in foreign companies and total employment in Shanghai, which indicates that FDI stimulates the labor market.

#### (4) Effects Related to the Three Sectors of Economy

### A. Model and Variables

Due to the diversity of the investment in the three sectors, the labor market shows a varied distribution, with Shanghai’s employment mainly concentrated in the tertiary sector. In order to have a more precise analysis of the effects on employment, this study has chosen the amount of capital invested (FDI1, FDI2 and FDI3) and Consumer Price Index (CPI) as explanatory variables, and employment in the primary, secondary and tertiary sectors as response variables (LAB1, LAB2 & LAB3) to run the regression analysis for the period of 1999 – 2008. In order to eliminate the multicollinearity and obtain a faultless regression output, the regression analysis was based on getting the natural log in this research. The details are listed in Tables 3, 4 and 5 in Appendix 1.

The amount of employment in the primary sector is LAB1, in the secondary it is LAB2, and in the tertiary it is LAB3. The actual FDI inflow to the primary is FDI1, to the secondary it is FDI2, and to the tertiary it is FDI2. The Consumer Price Index is CPI, and the reference period is 1999.

According to the condition of FDI in actual use in Shanghai, this study has turned the “Mei Haisheng” (2005) model into the following one:

Primary Sector:

$$\ln LAB_{1t} = \beta_0 + \beta_1 \ln FDI_{1t} + \beta_2 \ln CPI + \mu_t \tag{3}$$

Secondary Sector:

$$\ln LAB_{2t} = \beta_0 + \beta_1 \ln FDI_{2t} + \beta_2 \ln CPI + \mu_t \tag{4}$$

Tertiary Sector:

$$\ln LAB_{3t} = \beta_0 + \beta_1 \ln FDI_{3t} + \beta_2 \ln CPI + \mu_t \tag{5}$$

Table 3: Definition and Description of Model and Variable

Variable	Definitions and Descriptions
$\beta_0$	Constant
$\ln LAB_1$	log of employment in primary sector
$\ln LAB_2$	log of employment in secondary sector
$\ln LAB_3$	log of employment in tertiary sector
$\ln CPI$	log of CPI
$\mu$	random disturbance

### B. Results and Verification

The models were analyzed via Eviews3.1, and the verification results are as follows:

Primary Sector:

$$\ln LAB_1 = 25.292 - 0.010 \ln FDI_1 - 4.516 \ln CPI \tag{6}$$

t (6.995) (-0.133) (-5.821)  
 $R^2 = 0.83$  F=17.042

Secondary Sector:

$$\ln LAB_2 = 0.474 - 0.291 \ln FDI_2 + 1.484 \ln CPI \tag{7}$$

t (0.219) (-3.042) (3.049)  
 $R^2 = 0.671$  F=7.141

Tertiary Sector:

$$\ln LAB_3 = -2.776 + 0.182 \ln FDI_3 + 1.668 \ln CPI \quad (8)$$

t (-1.056) (3.399) (2.741)

$R^2 = 0.946$  F=61.560

The coefficients of determinations for the three models are 0.83, 0.671 and 0.946, respectively, which shows goodness of fit. The F-number in each equation is greater than the critical number, 4.74, which indicates that the result of the regression equation is significant. Under the condition that the significance level was preset at 5%, and the critical number is  $t_{0.025} (10-3) = 2.365$ , the t value corresponding to the FDI flowing to primary sector is -0.133, whose absolute value is less than  $t_{0.025} = 2.365$ . This indicates that FDI has no significant effect on the primary sector in Shanghai. But the t absolute values in the secondary and tertiary value are both greater than  $t_{0.025}$ , which means that the FDI has significant effects on the secondary and tertiary sectors in Shanghai.

The test on the model shows that each percentage point added to FDI will cause a 0.01 percentage point reduction of employment in the primary sector, and a 0.29 percentage point reduction of employment in the secondary sector, but will raise employment in the tertiary sector by 0.18 percentage point. The result signifies that FDI will not benefit the labor force's expansion in the primary and secondary sectors, but definitely will boost employment in the tertiary sector. The output meets the actual condition in Shanghai.

### 3.2 Effects from FDI on Quality of Employment in Shanghai

The quality of employment includes the working environment, the quality of the workers, the wages and benefits as well as the personal ability improvements. The following deems that FDI inflow has had significant effects on the quality of employment in Shanghai, but also that the effects are both positive and negative.

#### (1) Positive Effects

The effects are mainly on positive side, as FDI accelerates the improvement of the employment quality in Shanghai. This study deems that the improvements focus on wages, benefits and the development of individuals.

##### A. Wages

The foreign companies often offer better pay than the local ones and also provide better working environments. According to "Shanghai Statistical Yearbook", wages in foreign companies are often higher than the ones in the state-owned or the public sectors. For offer a more explicit view of wage conditions in the foreign companies, Table 4 discloses relevant information on the average wages in different kinds of enterprises.

Table 4: Average Wages in Shanghai between 1999 and 2006

Currency: RMB

	1999	2000	2001	2002	2003	2004	2005	2006
Foreign Companies	19728	21158	25572	26365	29106	29282	35709	40683
State-own Enterprises	16852	18865	21961	24719	28406	31287	36077	36010
Public Sector	11127	12020	13693	14851	16973	19986	22486	15209

Table 4 reveals that the average wages in foreign companies was higher than those in the state-owned enterprises and the public sector between 1999 and 2006. The wages in the foreign companies compared to the state-owned and public sectors were 1.13 times and 2.67 times greater, respectively.

#### B. Benefits and Terms

The foreign companies, especially the international giants, usually offer very competitive packages. “Five Insurances Plus One Fund” is the basic term; it includes pension, medical, work injury, unemployment and maternal insurance and house funds, and the terms might even surpass the basic ones. For example, Sony not only offers the basic “Five Insurances Plus One Fund”, but also free meals and house rental subsidies, wage raises each year, annual company travel, paid-annual leaves, hosting traditional holiday parties, birthday parties, karaoke competition, speech competition, athletic games, and year end dinner party. These benefits and terms are rare in the local companies.

#### C. Personal Ability Improvement

Foreign companies’ policies focus a lot on personal skills and improving working quality, so they usually provide new employees with working skills and abilities training. For example, Unilever’s subsidiary in Shanghai lays particular stress on strengthening employees’ international competitiveness. Unilever Shanghai has a comprehensive method for aiding employees’ improvement and development. There is a division which seeks in-house talents and future leaders. They assist the employees to obtain global perspectives through working, training courses and international relocation. In Unilever, all employees are open to improve themselves. Unilever Shanghai offers their employees abundant opportunities in learning, and the employees’ quality as well as working skills are thus upgraded.

In addition, foreign companies usually will found relevant R&D departments locally when entering a foreign market. The introduction of R&D departments always helps to enhance employees’ personal abilities. According to the statistics, until 2006, 257 foreign companies of “Fortune” top 500 enterprises had settled in Shanghai with 1884 investment projects and 45 R&D centers. The R&D and technical centers of foreign companies enable local engineers to obtain the latest know-how, which will improve human resources in Shanghai and build up their own talent pools. For example, Microsoft set up the “Microsoft China Technology Center (CTC)” in 1997. The center has introduced the latest technologies to Shanghai, where the software technologies were lagging behind, and provided training for employees related to the new technologies. A lot of outstanding IT engineers have been incubated since then.

FDI also has indirect effects on improving the quality of employment in Shanghai. Competition between foreign and local companies stimulates the local companies to improve their management and methods of production. As a result, the productivity of the local companies will increase, and job training will be strengthened, which will indirectly improve the employment quality in Shanghai.

#### (2) Negative Effects

Besides the positive effects stated in the previous paragraph, the FDI also has negative effect on the quality of employment in Shanghai, mainly on the stability of employment.

Numerous companies closed down due to the financial crisis in 2007, and countless employees were laid off. According to the

Shanghai Statistic Bureau, the employees hired by foreign companies numbered 1.2378 million in 2007, and the number was cut to 1.1138 million in 2008. That means the foreign companies cut redundant workers for cost-down reasons when encountering crises. However other figures show that the total employment in Shanghai was 9.0908 million people in 2007 and 10.5324 million in 2008, which signified growth of 1.44 million, so total employment increased instead of falling during the financial crisis. The growth occurred in the local companies, as the foreign companies had fewer workers during that time. From this perspective, employment in local companies is more stable than in foreign ones, which does not really benefit the quality of employment in Shanghai.

The trend of employment in foreign companies is to have shorter term contracts. When an enterprise faces falling profit, it will lay off workers without any hesitation, and as the workers have insufficient job security, this leads to poor employment stability.

#### **4. Conclusion**

On the basis of the empirical analysis on the effects of FDI on Shanghai, the conclusions regarding the quantity of employment, quality of employment and employment distribution of the three sectors of the economy, along with suggestions are as follows.

##### **(1) Quantity of Employment**

The regression analysis on FDI in relation to quantity of employment in Shanghai indicates that FDI will facilitate the growth of employment. From the viewpoint of employees hired by foreign companies, every \$100 million of actual FDI inflow to Shanghai will bring direct employment growth of 1470 people. For the total amount of employment, every \$100 million of actual FDI inflow will increase 1640 vacancies. FDI has created appreciable opportunities of employment in Shanghai through both direct and indirect effects in increased employment, but the effects are not really remarkable. From another point of view, according to the statistics, wages increased in Shanghai after the introduction of foreign companies, and that drove a huge amount of the labor force to relocate to Shanghai. Moreover, the foreign companies expanded the demand of local companies, further increasing the demands of the local labor market, which also boosted employment in Shanghai.

This research suggests that Shanghai should utilize its exceptional location, abundant labor force and enormous economic capabilities to attract more FDI inflow, to enable foreign companies to expand and create more job opportunities. In this stage, the types of FDI in Shanghai are mainly joint venture, wholly-owned and associated enterprise. Therefore, Shanghai can innovate its way of exploiting the FDI and develop more channels for increasing the inflow. Shanghai's Government could encourage the local private companies to have more interactions with foreign companies, and use these platforms for local companies to learn from foreign companies. The local private sector also can learn the methods of internationalizing, such as fund raising in the international financial market, joint venture or incorporation with foreign companies. Furthermore, Shanghai should further improve its mechanisms of labor market operation to encourage the flow of various professionals among different organizations, to take full advantage of the FDI and achieve full employment. Eventually, Shanghai should keep the economy growing stably, which will create more job opportunities.

##### **(2) Distribution of Employment**

The empirical analysis shows that FDI does indeed increase employment in the tertiary sector, but not the primary and secondary sector in Shanghai; however the effect on the tertiary sector is not prominent. This study deems the reason is that the tertiary sector in Shanghai is mainly low-end service industry instead of high-end.

This study suggests that Shanghai should put greater effort into enhancing employment in the primary and secondary sectors and increase job opportunities by offering more vacancies. On the other hand, Shanghai should encourage foreign companies to expand their investment in the tertiary sector, define further development and speed up developing the high-end service sector. Four fields

are proposed to be focused upon: financing and insurance, air logistics, specialized services and technological R&D. In the meantime, a relevant incentive policy should be drawn up in order to attract more FDI to Shanghai and effectively stimulate employment.

### (3) Quality of Employment

The FDI has both positive and negative effects on the quality of employment in Shanghai. FDI certainly enhances the quality of employment to a considerable degree, raises wages and, most significantly, offers training and of job skills improvement.

In regard to quality of employment, Shanghai City's Government should intensify the protection of employees in foreign companies and ensure at least minimal job security. The government should also provide seminars to assist the employees to learn the stipulations in contract regulations, to know and protect their rights, thereby enhancing their awareness of self-protection to improve their quality of employment.

The whole research reveals that large-scale FDI inflow will bring multiple effects. In general, FDI thrives on the labor market in Shanghai and increases the job opportunities in the tertiary sector as well as enhances the quality of employment. However, the expansion of the FDI diminishes employment in the primary and secondary sectors and also has some negative effects on the quality of employment. Therefore, Shanghai should keep expanding the scale of FDI on the one hand to increase the positive effects. On the other hand, FDI should be directed to the primary and secondary sectors, and the protection of employees in foreign companies should be intensified. Then the upgrading in the primary and secondary sectors can be expedited and the negative effects on the employment quality resulting from FDI will be reduced.

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# Designing Hydro Supply Chain for Water, Energy and Food

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The interconnected issues of water, food, energy and flood are among the most formidable challenges faced by developing countries around the world (Food and Agriculture Organization of the United Nations 2014). The development of hydropower has the potential to address all these issues in the same time and thus is prioritized in the international community to reduce poverty, promote the sustainable development of the economy, and achieve the Millennium Development Goals. In this paper, we apply supply chain management principles to water resource development and provide the end-to-end and dynamic perspectives needed in the expansion of hydropower network for energy, irrigation and flood control. We identify the unique features and economies of hydropower systems in developing countries and construct an integrated location optimization model to capture the conflicts of these issues, to explore the synergy among different sectors, and to maximize the overall benefit. The model links the hydropower location decisions with the distribution decisions of power and water, expresses the interaction among hydropower sites as in multi-echelon inventory systems, incorporates endogenously constrained budget, and captures a new set of cost and time trade-offs on the dynamically growing hydropower network. Applying the model to the real-life situation of Pakistan, we provide solutions that outperform common practices in all aspects of energy, irrigation, and flood control. Our results demonstrate the value of the supply chain perspectives on hydropower network expansion, and provide insights on the optimal development strategies regarding the size, location and mix of hydropower sites.

**Key words:** Developing Countries; Water, Food, Energy and Flood Nexus; Hydropower; Supply Chains; Not for Profit; Location Optimization

## 1 Introduction

"As the world charts a more sustainable future, the crucial interplay among water, food and energy is one of the most formidable challenges we face. Without water there is no dignity and no escape from poverty." United Nations Secretary-General Ban Ki-moon on his message for World Water Day 2011 (FAO 2014).

### 1.1 The Water, Food, Energy and Flood Nexus

Water is a blessing; it is not only an indispensable element of human life but also brings about many economic benefits, such as food and energy. However, achieving water, energy and food security for all is still one of the greatest challenges facing mankind. As of today, nearly one billion people lack access to safe drinking water, one billion people suffer from hunger and 2.5 billion people do not have access to electricity (FAO 2014).

Geographically, energy deficient regions are highly correlated with those facing food shortage and economic water scarcity. Southeast Asia and Sub-Saharan Africa are the regions in the world with the lowest electricity consumption per capita. For instance, two thirds of the population in Sub-Saharan Africa, about 585 million people, have no access to electricity (Rosnes and Vennemo 2012). The same regions also suffer severe malnutrition due to food shortage and economic water scarcity where water resources are abundant relative to that withdrawn for human benefits (Molden 2007).

The situation can get worse in the future as population growth and economic development accelerate demand for food, water and energy. The world population is expected to grow from 6.9 billion in 2010 to 9.1 billion in 2050. By 2050, global demand for food is predicted to increase by 60-70%, demand for energy and water will increase by 80% and 55% respectively (FAO 2014, UNESCO 2012).

Water is also a curse because flood is the top killer among all natural disasters. Globally, floods accounted for 31% of all natural disasters that occurred in the 20th century, but 84% of all disaster-related deaths between 2000 and 2005, and 65% of disaster-related economic losses between 1992 and 2001 (ADB 2013). Asia is the continent suffering the most from flood - during 1900-2012, flood disasters in Asia (40% of world's total) resulted in 6.8 million deaths (98% of deaths worldwide), displaced 3.4 billion persons (95% of affected persons worldwide), and caused \$330 billion (60% of world's total) in economic losses (ADB 2013, Sodhi and Tang 2014).

As advocated by Food and Agriculture Organization (FAO) of the United Nations in 2014, the issues of water, food, energy and flood are interconnected in the context of sustainable development of economy and society for developing countries. For instance, increasing agricultural output will substantially increase water consumption because agriculture accounts for 70% of the global freshwater withdrawal (FAO 2014). Seasonal fluctuations in precipitation cause floods and droughts alternatively. Running water in rivers can generate energy, and hydropower presents the largest renewable source of electricity generation. Finally, the economy of developing countries benefits from energy consumption and agriculture output but suffers from flood issues.

## **1.2 Hydropower Development - A Priority**

The development of hydropower has the potential of addressing the interconnected issues of water, food, energy and flood in the same time. Thus, it plays a critical role in sustainable development and economic prosperity of many countries. Hydropower systems provide not only electricity but also many economic benefits such as flood control, irrigation and water supply, by enhancing security against fluctuations in the availability of water and thus benefiting users throughout the year.

Hydropower is not only clean, efficient and flexible (to handle peak load) but also reliable and viable for massive energy production (IHA 2014). The generating cost of hydroelectricity is relatively low, making it a competitive source of renewable energy (Mirza, Ahmad, Majeed, Harijan 2008). Hydro reserves are widely available and the enabling technology is proven with relatively low technical requirement (e.g., relative to nuclear), thus they are accessible to and feasible for many developing countries. Currently, it provides a significant portion (15% in 2007) of the world's total electricity supply and is used in over 150 countries (World Energy Council 2013).

It is estimated that two-thirds of the world's economically feasible potential of hydropower is yet exploited (UNESCO 2012). Developing countries, such as those in Africa, Asia and Latin America, have an especially high percentage of unexploited hydro resources. For example, 12% of the world's hydropower potential is found in Africa, but only 5-10% of the potential is captured, in sharp contrast to the world's average of 20% (van der Wat 2013). Recognizing the potential of hydropower, the Beijing Declaration (Bhutto, Bazmi and Zahedi 2012) agreed at the United Nations Symposium on Hydropower and Sustainable Development in 2004 pledged "the developing countries and undeveloped countries to pay considerable attention and prioritize the development of hydropower for poverty reduction, achieving the Millennium Development Goals, promoting the sustainable development of the economy and society and improving the environment."

## **1.3 Challenges**

Many developing countries, including Pakistan, have prioritized hydropower projects. But significant challenges lie in the efficient exploitation and utilization of hydro-resources to meet the diverse needs of energy, food and flood control under limited financial resources.

As most rivers run from mountains to sea, a general problem is that the ideal hydropower locations (in capacity and/or scaled economies) are often located in mountain areas, far away from downstream plains where major demand zones of power and water are typically situated. Thus it is tricky to select hydropower sites that can achieve the scale economies and also minimize the yield losses in the distribution of power and water. The challenge is reflected by the significant disparity in practice, where countries like China (in 1950s) and Kenya (recently) promoted small hydros around the country, while Pakistan and Congo emphasized larger hydros in geologically ideal but more concentrated areas.

Pakistan is a case in point. Pakistan has rich hydro resources - the Indus river system runs across the entire country from the highest mountain in the world, the Himalayan in the north, to Arabic sea in the south within 1000 miles. About 11% of the collective hydropower potential is currently captured (Siddiqi, Wescoat, Humair and Afridi 2012).

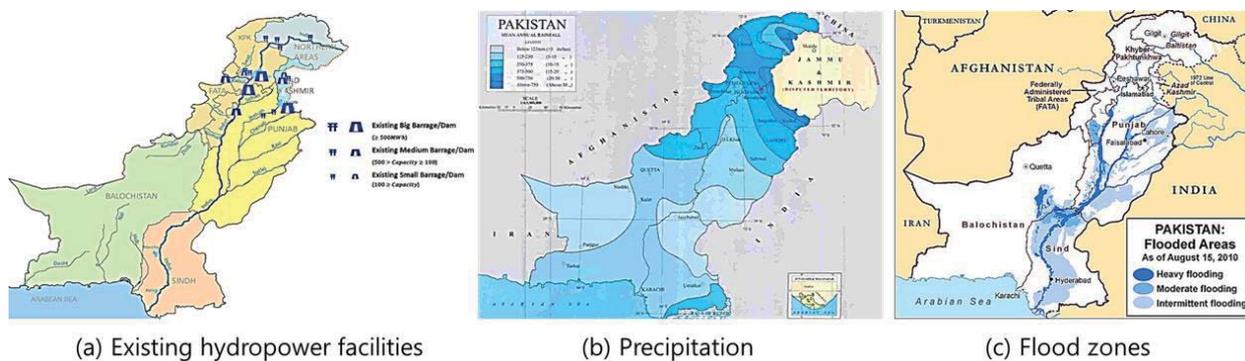


Figure 1: The case of Pakistan. Source: PPIB 2011

Most existing hydropower sites are located in the northern mountain area of the country (Figure 1 (a)). However, a significant and also seasonal precipitation occurs regularly in the downstream of these facilities (Figure 1 (b)), which cause severe floods (Figure 1 (c)) frequently. In Pakistan, floods account for nearly 91.4% in economic losses among all natural disasters; on average, the annual flood damage is around 1% of the annual GDP (Luo, Maddocks, Iceland 2015). Meanwhile, Pakistan suffers a significant energy deficiency in recent years (Malik 2012). Despite that agriculture contributes to about 25% of the GDP and 45% of employment, only about 50% of all agricultural land in Pakistan is irrigated (ADB 2013).

FAO (2014) called for quantitative studies and long-term planning of the nexus among water, food and energy for developing countries. In response to this call and also to resolve the related flood issues, we develop mathematical models in this paper to capture the nexus of water, food, energy and flood, and provide solutions and insights to efficiently expand hydropower network under limited budgets to meet the diverse needs of energy, irrigation and flood control. The objective is to effectively utilize the hydropower reserves to achieve the overall economic prosperity for developing countries.

#### 1.4 Hydro Supply Chains

In this section, we present the hydro supply chain concept to encompass the end-to-end perspective from hydropower network on a river system to the distribution of water and power to various demand zones. Specifically, a hydro supply chain includes the river system, hydropower facilities, water and energy demand zones, their linkages

to the hydropower facilities (transmission network, canal and pipe system), and flood zones (see Figure 2). Electricity is generated at hydropower facilities and distributed via the transmission network to energy demand zones (e.g., cities, industrial and commercial hubs); water is withdrawn by the hydropower facilities and distributed via the canal and pipe systems to water demand zones (e.g., farmland, cities). Finally, excessive water may overflow from the river basin to nearby flood zones. We note that energy demand zones may not overlap with water demand zones, and both demand zones can be far away from the river basin, along which flood zones are typically located.

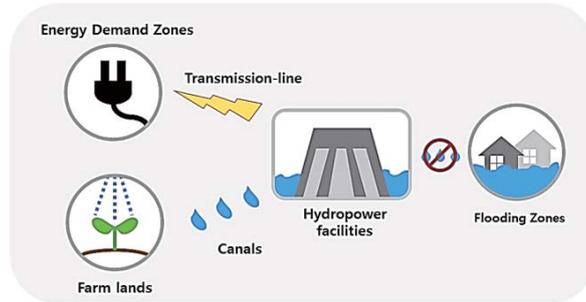


Figure 2: Hydro supply chain.

Despite many variations, there are essentially two types of hydropower facilities: a dam (with reservoir) and a barrage (without). A dam can generate energy and store water, thus it provides a buffer against fluctuations in precipitation to stabilize water supply and control flood. A barrage, on the other hand, can generate energy but cannot store water, thus it can hardly control flood and its water supply varies by season. Dams are typically more expensive and take longer to build than barrages of similar capacities. The type and capacity (power and storage) are site dependent (Silva 1991).

A hydro supply chain in a developing country has the following features and economics:

The hydropower network serves multiple needs including energy, irrigation and flood control. Water used for irrigation typically cannot be used for power generation.

Hydropower facilities with reservoirs (i.e., water storage capacities) can moderate the variation of water availability (e.g., precipitation) across seasons.

Consecutive hydropower facilities on the same river system interact with each other as they divide up local precipitation and one's flow control decisions (withdraw, release, store) affect all others.

Yield losses in power transmission (Kessides 2013) and water distribution (Miller 2009, Cullen 2004, Seckler, Molden and Baker 1998) cannot be ignored; evaporation loss on stored water must be considered (Mcjannet 2013).

Irrigation contributes to agriculture output; power consumption and agriculture contribute to the economy; less flood reduces the economic losses.

These features, except the yield losses in power transmission and the dependence between energy and economy, are unique to hydropower.

We take the standpoint of the government in developing hydropower systems. This is appropriate because in many developing countries, the government plays a leading role in the development of basic infrastructure through public budget. In the case of Pakistan, the government is represented by Water and Power Development Authorities

(WAPDA). Because of the interaction among hydropower development, economy and budget, the hydro supply chain concept also embraces the dynamic perspective driven by the (endogenous) economy-dependent budget. In this paper, we shall focus on strategic and tactical decisions such as hydropower site selection and sequence, distribution decisions of power and water to demand zones, and water control decisions (withdraw, release, storage).

### 1.5 Synergy, Conflicts and Dynamics

To optimally develop hydropower systems for multiple goals under limited financial resources, we shall identify the synergy, conflicts and dynamics in hydro supply chains.

**Interacting facilities, synergy and conflicts.** Working together, hydropower facilities can moderate seasonal precipitation and achieve the synergy between securing water supply for irrigation in the dry season and controlling flood in the rainy season. To maximize their collective potential, we must consider their interaction. Specifically, hydropower facilities on the same river system can interact with each other in a cascading way similar to multi-echelon inventory systems where the inflow to a facility includes the outflow of its immediate upstream facilities plus local precipitation. Thus, more water stored or used at upstream reduces the flow to downstream. The interaction leads to potential conflicts among consecutive hydropower sites, for instance, too many upstream dams can desertify downstream in the dry season; too few upstream dams can over-load downstream in the rainy season. Thus hydropower facilities must be planned jointly and spaced out strategically so they can work in harmony - complement rather than fight each other.

The needs of irrigation and flood control also inherently conflict with that of power generation because water used for irrigation cannot be used for power generation, and more water stored (more dams) for irrigation and flood prevention leads to more evaporation and less water for power generation. Because barrages are typically cheaper to build than dams, thus they are preferred to dams if there is no need to store water. Thus the conflicting needs lead to the issue of mix between dams and barrages, where the needs of power generation (or irrigation and flood control) may drive up the percentage of dams (barrages, respectively) in the mix.

**The cost trade-offs.** The design of hydro supply chain involves multiple cost trade-offs. First, we must balance between economies of scale in facility construction and yield losses in the distribution of water and power. Hydropower sites with ideal geological conditions (e.g., in mountain areas) may have a larger capacity and by scale economies, a lower unit cost, but they may be far away from the demand and flood zones, and so their potential is diminished via distance (due to yield losses). Sites close to the demand and flood zones (e.g., in plains) can meet the diverse needs at lower yield losses but may have a smaller capacity and a higher unit cost.

Second, the hydropower location must balance the needs of different sectors (development goals) because energy demand zones may not overlap with water demand zones and flood zones (see Figure 3 for an example of Pakistan). Thus the best hydropower location for energy may not be the best for irrigation and flood prevention. The cost trade-offs highlight the importance of hydropower location and its dependence on power and water distribution.

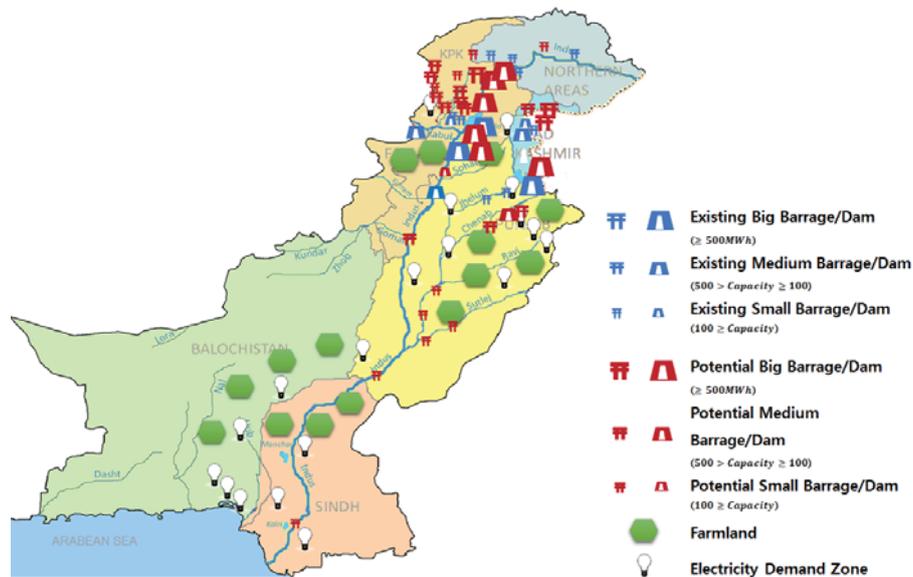


Figure 3: Pakistan map of existing and potential hydropower locations, demand and flood zones. Source: PPIB 2011.

Practice shows huge disparity in handling these cost trade-offs. For instance, economies of scale largely drove the site selection decisions in Pakistan (Figure 3) and Congo (Kermeliotis 2016) where a few sites with a large capacity were picked. Distribution losses drove the decisions in China in 1950s (Peng and Pan 2006) and Kenya (Kenya Ministry of Energy 2012) where many small sites were (or to be) built close to demand zones. In Pakistan and Congo, the hydropower facilities are highly concentrated in a relatively small region with ideal geological conditions (e.g., the far northern part of Pakistan, see Figure 3); in China and Kenya, the facilities were (to be) spread out across the entire country.

**The time trade-off.** In developing countries, the financial resources for infrastructure development often come from public funds that strongly depend on the economy, which, in turn, depends on energy consumption, irrigation and flood control. This limited and endogenous budget implies a dynamic interaction among budget, development and economy, where time is equally important as cost. For instance, a fast influx of new energy and irrigation water, and quick resolution to flood issues can boost economy quickly which leads to more budget available for future development.

Such an interaction implies a time trade-off in site selection in hydropower network expansion. Smaller sites are quicker to build and faster to impact but suffer higher unit costs; Barrages are faster to build than dams but have fewer functions. In practice, there is no consistent pattern on the sequence of site selection (e.g., large vs. small, barrage vs. dam) but a significant variety.

## 1.6 Research Questions and Main Results

The discussions of synergy, conflicts and trade-offs as well as disparities in practice lead us to more specific research questions: How to build up a hydropower network to effectively coordinate the synergy, balance the conflicts (among different development goals), and maximize the overall benefit? How does the location of hydropower sites depend on the distribution of power and water to dispersed and non-overlapping demand zones? How do

the limited financial resources and its resulting time trade-off shape up the best course of hydropower expansion decisions (location, size and type) over time? Should we build many small sites or a few large sites? Should we concentrate them or spread them out? How should we mix dams and barrages?

In this paper, we take a supply chain management perspective of water resources development in developing countries and define the concept of "hydro supply chains" which encompasses the end-to-end view (to include water and power distribution) and a dynamic view (driven by the economy-dependent budget). We mathematically model the nexus of water, food, energy and flood in hydro supply chains and present a new class of location optimization models to expand hydropower network under limited budget for energy, irrigation and flood control. The model captures the unique features and economics of hydropower development in these countries such as heavy yield losses in water and power distribution, synergy and conflict among multiple development goals, and the dynamic interaction among hydropower development, economy and budget (see Section 2 for more details). Applying the model to the real life case of Pakistan, we generate solutions that can greatly outperform some common practices in all dimensions of energy consumption, irrigation and flood control. The optimal solutions build more small hydros (dams and barrages) early on, and attempt to spread them out to meet diverse needs from dispersed demand and flood zones. In general, the optimal solutions mix facilities of different capacity and type - this hybrid approach differs from the practices that are either driven by economies of scale (a few big hydros) or distribution losses (many small hydros). Our results demonstrate the value of the supply chain perspectives in hydropower development by illustrating how the cost and time trade-offs shape up the optimal solutions. We also perform a sensitivity study to understand the impact of budget rations on the solution and performance. The rest of this paper is organized as follows: In Section 2, we review the related literature, point out the unique features of the problem considered in this paper, and elaborate on our contributions. In Section 3, we present assumptions, justifications and the modeling framework, as well as models to capture the facility interaction and the nexus of power, water (e.g., irrigation) and flood. In Section 4, we provide the mathematical formulation of the mix-integer programming (MIP) model. In Section 5, we apply the model to the real-life example of Pakistan to generate solutions and develop insights. Based on the discoveries, we also comment on the effectiveness of the practices used by a few countries. Section 6 concludes this paper.

## **2 Literature Review**

This paper lies at the interfaces of water resources management and development, energy system planning, and operations research and operations management. Based on operations research and operations management literature, this paper builds a location optimization model that extends the literature of water resource management and development to include energy distribution issues, and expands the literature of energy system planning to consider irrigation and flood control issues and model facility (dam) interaction. Thus, this paper contributes to the literature by providing an integrated mathematical model to capture the nexus of water, food, energy and flood and to optimize the overall benefit. The model provides new solutions and insights on the optimal development strategy of hydropower systems and allows us to assess the disparity in practice. In what follows, we shall review closely related work in each area and elaborate on the contribution of this work.

### **2.1 Water Resources Management**

The control of water flow in multi-reservoir systems has been studied extensively in the water resource management literature. The decisions are centered around water storage, routing, usage and releasing subject to a variety of problem specific constraints, for purposes such as energy generation (Grygier and Stedinger 1985), flood control

(Windsor 1973), and irrigation (Cai, McKinney, Lasdon 2002). Yeh (1985) and Wurbs (1993) provide reviews of this area with respect to the issues, models and optimization algorithms. More recent work also included water distribution, deliveries and movement among regions, please see Jenkins, et al. (2004) and Harou, et al. (2009). Cai, et al (2002) considers distribution efficiency in water resource management for irrigation. Hu, et al. (2015) describes an application to optimize the generation portfolio of a six-dam system in real time to meet the requirements of flood control and electricity reliability under uncertainty. However, this literature focuses on the optimal control and management of established water resource systems without network expansion and location decisions.

## **2.2 Capacity Expansion in Water Resource Systems**

Capacity expansion planning of water resource systems determines future expansion in time, size and locations of assets to meet the increasing demand of a specific commodity. The early work in this literature focuses on sequencing capacity expansion projects for power and/or water demand without considering the spatial configuration of the system (e.g., Erlenkotter 1973). O'Laoghaire and Himmelblau (1971, 1972, 1974) study the expansion of hydropower network on a river system to optimize net irrigation and energy benefit subject to budget, demand, flow balancing and institutional constraints. The flow control issues are modeled in this literature by many authors, such as Martin (1987) which separates the problem into capital investment and system operation subproblems, and solves them by network optimization models and a dynamic programming algorithm. Luss (1982) provides a thorough review of general capacity expansion models with applications in water resources development. More recent work in this literature considers water distribution decisions. For instance, Hsu, et al. (2008) provides a network flow model to optimize water distribution which helps to identify the bottlenecks. Based on the results, capacity expansion alternatives are proposed and evaluated iteratively. Beh, et al. (2014) studies the sequencing of water supply projects by incorporating alternative supply sources and multiple objectives, including cost and greenhouse gas (GHG) emissions. Padula (2015) provides a thorough review of the recent development in this literature.

Most work in this literature focuses on developed countries, from which developing or undeveloped countries have many distinct features:

The interconnected issues of energy, water (irrigation) and flood are equally important for the economy and society.

Heavy yield losses in power and water distribution due to aging and poorly maintained infrastructure.

The hydropower facilities are barely existent, government often takes the lead in the development through public funds, which depend on economy, and in turn, the development of water resource systems.

Developed countries are quite on the contrary, where the system is well established and it is often the market and individual companies that drive the development while government plays an indirect role by designing policies. In developed countries, flood is often a lesser issue than energy and water supply and thus rarely considered together with the other two. Likewise, yield losses can be minor and many studies do not consider dispersed demand zones but just lump all demand together regardless of their locations. This literature rarely considers power distributions and their yield losses; it either does not consider budget or consider exogenous budget.

Our work incorporates these distinct features and contributes to this literature in the following ways: First, we expand the existing literature to include all three development goals, i.e., energy, water and flood, by mathematically

modeling their nexus to capture their synergy and conflicts. Second, we provide the end-to-end perspective to this literature by including both power and water distribution decisions with distance-based yield losses in hydropower network expansion. Third, we consider endogenous budget that depends on the economy, which in turn, depends on effective exploitation and utilization of hydro resources.

### **2.3 Energy System Planning**

The literature plans integrated energy systems with a portfolio of power generating technologies (including hydropower) at a strategic level for a country or a region. One most notable class of models, the MARKAL family models, aims at minimizing the total cost of providing energy to meet the demand of diverse industry sectors. The MARKAL-MACRO model further links energy system planning to macro-economics through supply-demand dynamics and energy cost. We refer the reader to Connolly, Lund, Mathiesen and Leahy (2010) for a thorough review. Models in this literature typically do not consider budget constraints except Kuby, et al. (1993) which provides a strategic planning model for China's thermal, hydro and nuclear power generations, fuel transportation, and electricity delivery under exogenous budgets.

Most work in this literature focuses on cost efficiency and environmental issues – important to developed countries, but it does not model the interaction among hydropower facilities, and has yet considered energy, irrigation and flood control issues jointly – important to developing countries (FAO 2014). As pointed out by Urban, Benders and Moll (2007) and Bhattacharayya and Timilsina (2010), existing models established for developed countries may not be appropriate for developing countries because of the distinct features, some of which are specified in Section 2.2 in the context of hydropower development. The combination of these features is rarely studied in this literature but can play a significant role in the expansion of hydropower networks. Our work extends the energy system planning literature to include irrigation and flood control, and capture the unique features of hydropower systems in developing countries.

### **2.4 Operations Research and Operations Management**

The flow control problem of a multi-reservoir system bears much similarity to the inventory control problem in multi-echelon inventory systems. Specifically, the flow control model with evaporation loss is similar to a multi-echelon inventory model with external demand and supply at every stage where inventory is subject to deterioration proportional to the storage time (see, e.g., Zipkin 2000, Simchi-Levi and Zhao 2012). Our paper uses the flow control model with predictable inflows and demand as a building block in the optimal expansion of the hydropower network.

The dynamic facility location problem with budget constraints provides many modeling techniques and solution approaches useful for our study, we refer the readers to Daskin, Snyder and Berger (2005), Snyder (2006) and Shen (2007) for thorough reviews of the literature. Rafique, Mun and Zhao (2015) develops a location optimization model to build up coal-fired energy supply chain under limited budget for energy security and economic prosperity. They consider both cost and time trade-offs in the energy sector and provide not only optimal but also politically feasible solutions.

This paper generalizes the energy supply chain concept of Rafique, et al. (2015) from coal to hydro resources to encompass much broader issues from energy to irrigation and flood control. These issues have synergy but also conflicts, and lead to different cost trade-offs. Specifically, rather than a balance between inbound and outbound costs for coal-fired energy supply chains, the cost trade-offs for a hydro supply chain are driven by the balance between economies of scale and yield losses, as well as conflicting development goals in different sectors. Second,

hydro resource has different features and economics from coal, for instance, it does not have fuel transportation issues but the interaction of facilities and seasonally varying requirement; each potential site has specific type, cost, and time for its hydropower facility. Third, the time trade-off is broadened from the energy-economy cycle (coal) to the water-economy cycle (hydro), where energy, agriculture (irrigation) and flood control all contribute significantly to the economy, but they share the water resources and pull hydropower locations in different directions. In this paper, we develop new models, solutions and insights for hydro-resource planning of developing countries to capture the energy, irrigation and flood nexus. Finally, recent research on socially responsible operations has shown great promises in both theory and practice. For instance, Dawande, Gavirneni, Mehrotra and Mookerjeeet (2013) studies the efficiency and equity in irrigation water distribution between primary and secondary farms, and designs decentralized and individually rational mechanisms to achieve socially optimal distribution of surface water in a farming community. Our work contributes to this growing body of knowledge by studying the interconnected issues of water, energy, food and flood in developing countries for the sustainable development of the economy.

### 3 Modeling Framework

In this section, we present our modeling framework for the hydro supply chain from interacting hydropower facilities to water and power distribution, and to diverse demand and flood zones. We shall first make assumptions and justify them in Section 3.1, and then describe the mathematical model of flow control (namely, the cascading model) in Section 3.2. We next model the nexus of water, energy and flood in Section 3.3, and present the framework of the mathematical model in Section 3.4.

#### 3.1 Assumptions and Justifications

Figure 4 provides an overview of the network structure.

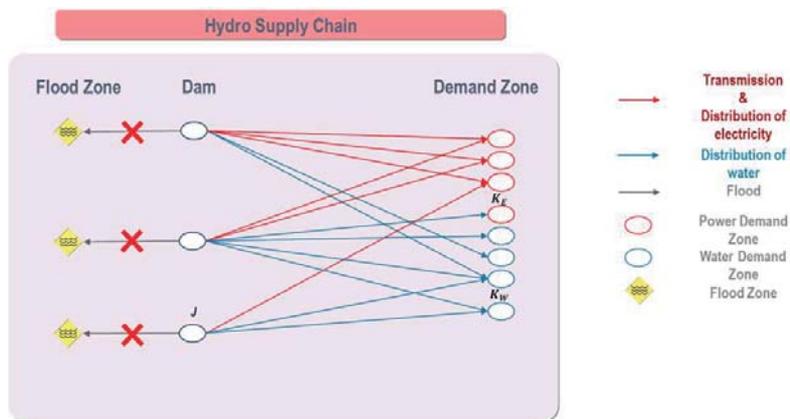


Figure 4: A hydro supply chain model.

A hydro supply chain consists of the following key elements: the river system, hydropower sites, distribution (power and water) networks, and demand and flood zones. The input to the river system (precipitation, surface and underground water) is exogenous and studied extensively by natural science disciplines, such as hydrology, meteorology and geology. The hydropower sites (existing and potential) can be managed by either government agencies (e.g., WAPDA in Pakistan) or private companies. Likewise, power and water distribution can be managed by either public or private transmission, irrigation and utility companies.

We make the following general modeling assumptions.

**Assumption 1** *General assumptions on the hydro supply chain:*

The river system has a tree structure where potential hydropower locations are identified, indexed by  $j \in J_p$  where the set  $J_p$  has a cardinality  $J_p$ . For each location, there is an ideal type of hydropower facility with known parameters such as construction cost and time, installed capacity (for power), storage capacity (for water) and energy conversion rate (from water flow to energy generation). The existing hydropower facilities are indexed by  $j \in J_E$  (cardinality  $J_E$ ) with known locations and parameters. Let  $J = J_p \cup J_E$  and  $J$  be the cardinality. We define segment  $j$  of the river system to be the river basin between location  $j \in J$  and all of its immediate upstream locations.

We consider a planning horizon of multiple periods (one period = a season = half a year) as indexed by  $t = 1, 2, \dots, T$ .

All major demand zones (each at a different location) are identified. There are two types of demand zones: Electricity demand zones,  $K_E$ , indexed by  $k = 1, 2, \dots, K_E$ , and water demand zones (e.g., farmland),  $K_W$ , indexed by  $k = 1, 2, \dots, K_W$ . Demand (for electricity and water) can be projected for each demand zone in each period of the planning horizon.

Water used for irrigation cannot be used for power generation.

A hydropower site can serve any electricity demand zone but cannot supply water to a water demand zone too far upstream. An energy (water) demand zone can be supplied by multiple hydropower sites.

The annual (real) GDP depends strongly on power consumption, irrigation and flooded water in that year.

The public fund allocated to the development of hydropower each year depends on the past year's real GDP.

The construction of a hydropower facility must be completed without preemption.

All non-hydropower related existing power supplies (e.g., oil and gas) and water supplies (e.g., wells and lakes) run as BAU (business as usual).

The first assumption in Assumption 1 holds true in general for most developing countries. Potential hydropower sites and their parameters depend on many factors such as topography, geology, hydrology, and land use (Baban and Wan-Yusof 2003). Each site is unique and ideal either for a dam or a barrage. For instance, barrage is generally built on flat terrain across wide and meandering rivers, while the best places for building a dam is a narrow part of a deep river valley. The second assumption is based on the monsoon seasons (or dry and rainy seasons) which take place in many developing countries in tropical areas, ranging from south Asia, Sub-Saharan Africa, to Latin America. These seasons last from 4 months to 7 months and have clearly recognizable patterns of precipitation. The third assumption holds true because energy demand at an aggregated level of a demand zone generally follows patterns that are documented and can be projected by the government. Similarly, the water demand (e.g., for irrigation) can be estimated at an aggregated level for each major farming area in each season by the government. The fourth assumption can be justified by the water resources management literature, please see O'Laoghaire and Himmelblau (1974), Grygier and Stedinger (1985), and Cai, McKinney and Lasdon (2002). The fifth

assumption holds because it is not practical for a hydropower facility to supply water to demand zones too far upstream due to the significant energy required to pump up water, additional cost required to build temporary water storages, and yield (e.g., seepage) losses in water distribution.

To justify the sixth assumption, we first note that the dependence of economy (GDP) on energy consumption is well documented for Pakistan (Tang and Shahbaz 2013) and other countries (Menegaki 2014). Second, agriculture often contributes significantly to the GDP for developing countries. Because agriculture output depends strongly on water supply (Dawande, et al. 2013), irrigation is critical to the GDP. Third, flood damage reduces GDP - a fact well studied for Pakistan in particular (ADB 2013) and other countries in general (Shabnam 2014). The dependence is verified by our empirical study based on Pakistan's data (Section 5). The seventh assumption comes from the government's public funding allocation practice (Federal Budget Publications of Pakistan 2014-15). In each year, a certain percentage of the total available fund is allocated to the energy sector (with a portion going to hydropower), where the total amount depends on the economic status (GDP), and the percentage depends on competing priorities and has to be decided by the government. We use real GDP to eliminate the impact of inflation. The eighth assumption is made based on the common practice in Pakistan. We make the last assumption to focus on hydropower development.

### 3.2 The Cascading Model

The cascading model (or flow balance model) is developed and studied in the water resource management literature, see Windsor (1973) and Grygier and Stedinger (1985). Because of the central role that it plays in the optimization of the much broader hydropower development problem, we present a concise expression of this model for river systems of a general topology. We make the following assumptions.

#### **Assumption 2** *Water flow assumptions:*

The net (external) inflow at each segment of the river, including local precipitation, underground and surface water (but not water from the upstream of the river system) less leakage, can be forecasted for each period of the planning horizon.

Evaporation loss of stored water in dams (with reservoir) cannot be ignored but such loss of running rivers can be ignored.

To justify the first assumption in Assumption 2, we note that governments typically have detailed meteorological and hydrological data, based on which one can estimate the net external inflow for each segment of the river system. The second assumption is valid because the annual evaporation loss of stored water in dams can be 40% in topical areas (Miller and Spoolman 2009, O'Laoghaire and Himmelblau 1974). However, evaporation loss of running water in rivers is negligible due to the short time of exposure. For instance, a running river at a normal speed of 5 miles per hour just takes 200 hours (less than 10 days) to cross 1000 miles.

To present the cascading model in a general structure river system, we introduce a concise notation - the adjacent matrix. For each hydropower location  $j \in J$ , we identify the immediate upstream locations  $j' \in J$  by a matrix,  $X$ , of the following form: for  $j' \neq j$ ,  $X_{j,j'} = 1$  if  $j'$  is an immediate upstream location of  $j$ ,  $X_{j,j} = 0$  otherwise. Figure 5 shows an example of a river system with multiple branches and hydropower sites, and the corresponding  $X_{j,j'}$ .

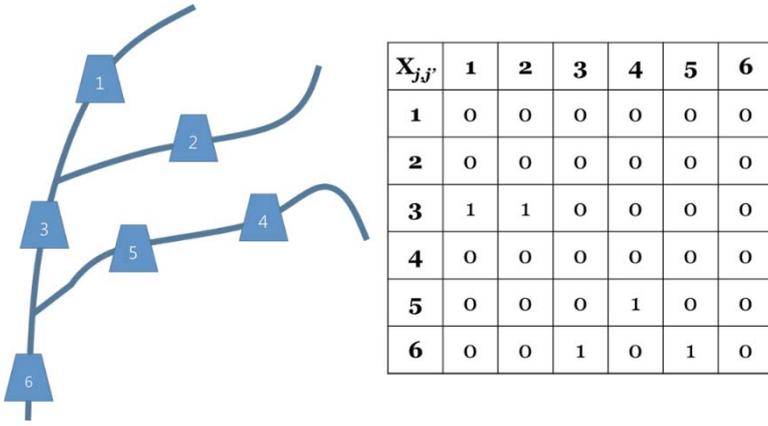


Figure 5: An example of a river system and the  $X_{j,j'}$ .

In general,

$$\sum_{j' \neq j} X_{j,j'} = \begin{cases} 0 & \text{if } j \text{ is at the most upstream,} \\ > 1 & \text{if } j \text{ is at a merged point of multiple branches,} \\ 1 & \text{otherwise.} \end{cases} \quad (1)$$

We now introduce notation by following the convention of using upper-case letters for parameters and lower-case letters for variables.

$A_{j,t}$ : Net external inflow to segment  $j$  of the river system (that is, the river basin between location  $j$  and all of its immediate upstream locations) in period  $t$ .

$\eta$ : The yield after accounting for evaporation loss for the stored water in reservoirs for a period.

$s_{j,t}$ : The stored water at location  $j$  at the end of the period  $t$ .

$C_j$ : The (water) storage capacity of the facility in location  $j$ .

$u_{j,k,t}$ : Water used (withdrawn) in the period  $t$  from location  $j$  for demand zone  $k$ .

$q_{j,t}$ : Total water flowing into location  $j$  in period  $t$ .

$o_{j,t}$ : Total water flowing out of location  $j$  in period  $t$  to the river downstream; note that  $o_{j,t}$  does not include  $u_{j,k,t}$ .

Clearly, the water flow into location  $j$  is (see Figure 6),

$$q_{j,t} = \sum_{j'} X_{j,j'} \times o_{j',t} + A_{j,t}. \quad (2)$$

To write out the flow balance equation at location  $j$ , we consider two cases: If a hydropower facility is in operation at location  $j$  in period  $t$ , then water stored at location  $j$  at the end of period  $t$  is,

$$s_{j,t} = \eta \times (s_{j,t-1} + q_{j,t} - o_{j,t} - \sum_k u_{j,k,t}), \quad s_{j,t} \leq C_j. \quad (3)$$

Otherwise, if a hydropower facility is yet in operation at location  $j$  in period  $t$ , then

$$o_{j,t} = q_{j,t}, \quad s_{j,t} = u_{j,k,t} = 0 \quad \text{for all } k. \quad (4)$$

### 3.3 The Water, Energy and Flood Nexus

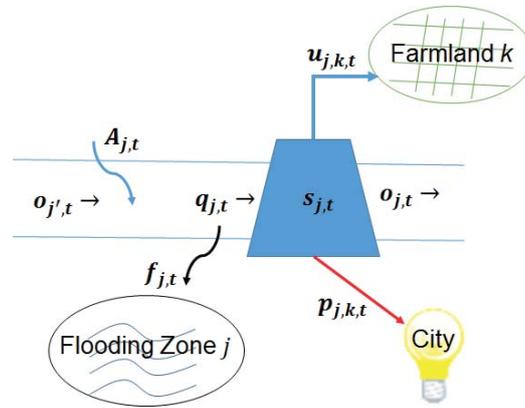


Figure 6: The water, energy and flood nexus in the context of hydropower.

Figure 6 illustrates the water, energy and flood nexus in the context of hydropower. We first discuss the model for flood and its connection to the cascading model.

**Assumption 3** *Flood control assumptions:*

Because all flood zones are located next to rivers, we group flood zones near location  $j$  and denote them by flood zone  $j$ . We assume that flood zone  $j$  can only be affected by the upstream hydropower facilities of location  $j$ .

Each flood zone has a tolerable peak flow per period; exceeding which results in flood.

All flooded water in flood zone  $j$  eventually flow back to rivers (to location  $j$ ).

The first assumption in Assumption 3 is made without loss of generality as the flooding areas are mostly affected by rivers nearby and we have the flexibility of grouping the flood areas. The peak tolerance per period serves as a proxy for the maximum flow that can pass location  $j$  without causing flood. The third assumption follows research in hydrology (see, e.g., Ali 1993).

For flood zone  $j$ , we define  $MT_j$  to be the peak tolerance (in billion cubic meters) per period. Because  $q_{j,t}$  is the total amount of water flowing by flood zone  $j$  in period  $t$ ; if  $q_{j,t} > MT_j$ , then flood occurs at flood zone  $j$  in the amount of  $f_{j,t} = q_{j,t} - MT_j$ . Otherwise, i.e.,  $q_{j,t} \leq MT_j$ , zone  $j$  is not flooded.

We then discuss the model for water supply (e.g., irrigation).

**Assumption 4** *Water supply assumptions:*

The water distribution system, e.g., canals and pipes, has been established and operative. Thus we only need to build passages (or pumping stations) for each new hydropower facility to connect it to the nearest water distribution system.

There is a upper limit on the amount of water that can be withdrawn at each hydropower location.

Loss and leakage (e.g., seepage, technical loss) in water distribution are non-negligible and distance dependent. The yield is  $\gamma$  per 100 miles.

The first assumption in Assumption 4 holds true in Pakistan and many developing countries where agriculture contributes significantly to the GDP and irrigation systems are established. The second assumption is based on the capacity limits of canals and pipelines (Barber 2009). The third assumption comes from the statistics of significant losses in water delivery and irrigation distribution (Cullen 2004, Miller and Spoolman 2009). Thus, suppose  $u_{j,k,t}$  is withdrawn from location  $j$  for water demand zone  $k$ , then only  $\gamma^{D_{j,k}} \times u_{j,k,t}$  can reach zone  $k$  where  $D_{j,k}$  is the distance between  $j$  and  $k$  (in 100 miles).

We lastly discuss the model for power supply.

**Assumption 5** *Power supply assumptions:*

Transmission system has been installed and operative. Thus we only need to build grid stations at each potential location and hook them up with the nearby transmission system.

The power generation at location  $j$  is proportional to  $o_{j,t}$  as determined by the conversion ratio and bounded by the installed generating capacity.

The distribution of power via transmission systems is subject to yield loss, and the yield is  $\omega$  per 100 miles.

The first assumption in Assumption 5 holds true in Pakistan and many developing countries. The second assumption follows the fourth general assumption in Assumption 1. This assumption is also based on the fact that hydropower generation depends on both water head and water flow, and the conversion ratio connects the water flow with power generation. The yield loss in power transmission is well studied, see Hurlbut (2012). Thus, suppose  $p_{j,k,t}$  is the power supplied from location  $j$  to power demand zone  $k$ , then only  $\omega^{D_{j,k}} \times p_{j,k,t}$  can reach and be consumed by zone  $k$ .

**3.4 The Modeling Framework**

We shall describe the key components of the mathematical model and their connections before providing the full detail of the mathematical programming formulation in Section 4.

As discussed in Section 1.4, we take the standpoint of the government in this paper. Thus our ultimate objective is economic prosperity of the country, to which all sectors (energy, agriculture and flood control) contribute. To this end, we shall set the objective of our mathematical model to maximize the total discounted real GDP over a given planning horizon. GDP unifies the development goals across different sectors by dollar value, and is one way to represent the overall benefit of the system. The dependence of GDP on energy consumption, irrigation (through agriculture) and flooded water is justified in Assumption 1 and verified by a multiple regression model for Pakistan (Section 5.1).

The mathematical model involves the following decision variables: when to set up which hydropower site, which site supplies which energy and water demand zones, and water control decisions (store, withdraw and release) at each facility in operation.

The **constraints** are grouped by echelons and sectors as follows.

**Flow control constraints:** The cascading model on water flow (e.g., flow balance equations, water storage capacity).

**Hydropower site constraints:** A hydropower facility can be set up only once at each potential location; capital cost calculations.

**Water supply constraints:** The system cannot supply more water than what is needed at each demand zone; water withdrawn at a location is subject to the availability of the facility and the capacity of the distribution system; water cannot be distributed too far upstream.

**Power supply constraints:** The conversion of water flow into power; power generation at a location is subject to the availability of the facility and bounded by the installed capacity; network constraints to connect power generated, distributed, and demanded.

**Flood constraints:** To calculate the flooded water in each flood zone.

6. **Budget constraints:** The budget is limited and depends on the GDP.

The flow control constraints connect all hydropower facilities on the river system where adding one facility affects the operations and performance of all others. The water, power and flood constraints bridge the hydropower expansion decisions with distribution (water and power) decisions and flood damages. These constraints also link water flow with power generation and flood, and account for capacity limits and demand requirement of different sectors. The hydropower site constraints provide regularity conditions on the expansion of hydropower network and calculate the capital expenditures. Finally, the budget constraints connect GDP with available funding for future development of the hydropower network.

The mathematical model is challenging to solve as even the optimal control of multi-reservoir systems (a subproblem) requires sophisticated optimization tools (Yeh 1985). We shall construct a mixed integer and linear programming model (MILP) in Section 4 to solve this problem.

#### 4 Mathematical Programming Formulation

In this section, we present the mathematical programming formulation for the optimal design of hydro supply chains to meet multiple needs from diverse demand and flood zones. We define indices in Table 1, which is followed by decision variables in Table 2 and intermediate variables in Table 3. All decision variables are non-negative.

Index	Name	Set
$j$	Hydropower facility locations (sites) and flood zones	$J = J_E \cup J_P$
$k$	Electricity and water demand zones	$K = K_E \cup K_W$
$t$ or $t'$	Time (unit: period = half a year or a year)	$\{1,2,\dots,T\}$ or $\{1,2,\dots,T/2\}$ , $T$ : an even number

Table 1: Indices

Hydropower Facility			
$w_{j,t}$	1 if the facility in location $j$ enters service in	Binary	N/A

	period $t$ , 0 otherwise		
<b>Water Control</b>			
$o_{j,t}$	The amount of water released in period $t$ from location $j$	Continuous	Unit: Billion Cubic Meters
$u_{j,k,t}$	Water withdrawn at location $j$ for demand zone $k$ in period $t$	Continuous	Unit: Billion Cubic Meters
$s_{j,t}$	Water stored at location $j$ at the end of period $t$	Continuous	Unit: Billion Cubic Meters
<b>Power Supply</b>			
$e_{j,t}$	Electricity generated at location $j$ in period $t$	Continuous	Unit: MWh
$p_{j,k,t}$	Power supplied from location $j$ to demand zone $k$ in period $t$	Continuous	Unit: MWh
<b>Flood</b>			
$f_{j,t}$	Flooded water at location $j$ in period $t$	Continuous	Unit: Billion Cubic Meters

Table 2: Decision Variables

<b>Hydropower Facility</b>			
$q_{j,t}$	Water flow into location $j$ in period $t$	Continuous	Unit: Billion Cubic Meters
$b_{j,t}^{HPP1}$	Cost to setup hydropower facility at location $j$ in period $t$	Continuous	Unit: Million US \$
$b_t^{HPP2}$	Total cost to operate hydropower facilities in period $t$	Continuous	Unit: Million US \$
<b>Budget and GDP</b>			
$g_{t'}$	GDP in year $t'$	Continuous	Unit: Million US \$

Table 3: Intermediate Variables

#### 4.1 Objective Function

Let  $\beta_{t'}$  be a series of time discounted factors decreasing in  $t'$  where  $t'$  is a time index in years (Table 1), then the objective function, i.e., the total discounted GDP over a finite planning horizon  $T$ , is,

$$\sum_{t'=1}^{T2} \beta_{t'} \cdot g_{t'} \rightarrow \text{Max} \quad (5)$$

where  $g_{t'}$  is given in the following form.

$$g_{t'} = a_0 + a_1 \cdot \left[ \sum_{j \in J} \sum_{k \in K_E} \frac{\Omega_{jk}}{2} (p_{j,k,2t'} + p_{j,k,2t'-1}) \right] + a_2 \cdot \left[ \sum_{j \in J} \sum_{k \in K_W} \Gamma_{jk} (u_{j,k,2t'} + u_{j,k,2t'-1}) \right] + a_3 \cdot \left[ \sum_{j \in J} (f_{j,2t'} + f_{j,2t'-1}) \right]. \quad (6)$$

Here,  $\Omega_{jk} = \omega^{D_{jk}}$  is the power transmission yield between location  $j$  and demand zone  $k \in K_E$ ,  $\Gamma_{jk} = \gamma^{D_{jk}}$  is the water distribution yield between location  $j$  and demand zone  $k \in K_W$ , and  $D_{jk}$  is the distance between

$j$  and  $k$ . Eq. (6) shows the dependence of the GDP on power consumption (first term), water consumption (second term) and flood (third term) through country-specific parameters,  $a_0, a_1, a_2, a_3$ , which can be estimated by empirical studies based on real data.

## 4.2 Flow Control Constraints

By the cascading model in Section 3.2, we have the following constraints on the inflow, storage, usage and outflow at each hydropower location.

$$q_{j,t} = \sum_{j'=1}^J X_{j,j'} \times o_{j',t} + A_{j,t}, \quad \text{for } j \in J \text{ and } t=1,2,\dots,T, \quad (7)$$

and

$$s_{j,t} = \eta \times (s_{j,t-1} + q_{j,t} - o_{j,t} - \sum_{k \in K_W} u_{j,k,t}), \quad \text{for } j \in J \text{ and } t=1,2,\dots,T, \quad (8)$$

and

$$s_{j,t} \leq C_j \quad \text{for } j \in J \text{ and } t=1,2,\dots,T. \quad (9)$$

The first two constraints connect different hydropower sites via the cascading model, the third constraint honors the water storage capacity at location  $j$ .

To ensure that Eq. (4) holds for non-operative locations, we also need,

$$s_{j,t} + \sum_{k \in K_W} u_{j,k,t} \leq M \cdot \sum_{\tau=0}^t w_{j,\tau}, \quad \text{for } j \in J_p \text{ and } t=1,2,\dots,T, \quad (10)$$

where  $M$  is a constant selected for the big M method. This constraint implies that if location  $j$  is not in service, water can neither be stored nor withdrawn to meet demand.

## 4.3 Hydropower Site Constraints

The first set of constraints for hydropower sites specifies their availability. Because a hydropower site can only be setup once, thus

$$\sum_{t=1}^T w_{jt} \leq 1 \quad \text{for } j \in J_p. \quad (11)$$

The second set of constraints for hydropower sites calculates their capital costs. For potential location  $j \in J_p$ , the setup cost in period  $t$  (in million \$),  $b_{jt}^{HPP1}$ , can be written as follows,

$$b_{jt}^{HPP1} = IC_j \cdot \sum_{\tau=t+1}^{t+T_j} w_{j\tau} \quad \text{for } j \in J_p \text{ and } t=1,\dots,T-T_j, \quad (12)$$

where  $IC_j$  is the capital investment per period for setting up the hydropower facility at location  $j$  assuming that the total investment is evenly distributed over the setup time  $T_j$ .

Because setting up the hydropower facility takes multiple periods, it is logical to assume that we do not start setting up location  $j$  after the  $T - T_j$ th period as the facility will be ready beyond the planning horizon and thus cannot contribute to the objective function. Therefore the ending conditions for location  $j \in J_p$  are

$$b_{jt}^{HPP1} = IC_j \cdot \sum_{\tau=t+1}^T w_{j\tau} \quad \text{for } j \in J_p \text{ and } t=T-T_j+1,\dots,T-1, \quad (13)$$

and

$$b_{jT}^{HPP1} = 0 \quad \text{for } j \in J_p. \quad (14)$$

Finally, the operating cost of all hydropower facilities in year  $t$ ,  $b_t^{HPP2}$ , is given by

$$b_t^{HPP2} = \sum_{j \in J_P} OC_j \cdot \sum_{\tau=1}^t w_{j\tau} + \sum_{j \in J_E} OC_j \quad \text{for } t=1, \dots, T, \quad (15)$$

where  $OC_j$  is the operating cost of the hydropower facility at location  $j$  per period. Note that  $b_t^{HPP2}$  includes the operating costs of both existing and newly built facilities.

#### 4.4 Water Supply Constraints

The first set of constraints for water supply ensures that the total amount of water supplied to each demand zone is not greater than the amount of water demanded. Let  $G_{kt}^W$  be the water gap (or shortage) at demand zone  $k$  in period  $t$ , then

$$\sum_{j \in J} \Gamma_{jk} \cdot u_{j,k,t} \leq G_{kt}^W \quad \text{for } k \in K_W \quad \text{and } t=1, \dots, T, \quad (16)$$

where  $\Gamma_{jk}$  is the yield in water distribution from location  $j$  to demand zone  $k$  (see Section 4.1).

The second set of constraints for water supply captures the special restrictions in water distribution, such as, a hydropower location cannot serve a water demand zone too far upstream (Assumption 1). We define the water distribution feasibility matrix  $Y_{jk}$ , where  $Y_{jk} = 0$  implies that it is infeasible to supply water from  $j$  to  $k$ ,  $Y_{jk} = 1$  otherwise. Thus,

$$u_{j,k,t} \leq M \times Y_{jk} \quad \text{for } j \in J \quad \text{and } k \in K_W \quad \text{and } t=1, \dots, T, \quad (17)$$

where  $M$  is a constant selected for the big M method.

The third set of constraints is on the capacity limits of the water distribution system at each location. Let  $r_j$  be the maximum fraction of the water flowing into location  $j$  that can be withdrawn, then

$$\sum_{k \in K_W} u_{j,k,t} \leq r_j \times q_{jt} \quad \text{for } j \in J \quad \text{and } t=1, \dots, T. \quad (18)$$

#### 4.5 Energy Supply Constraints

The first set of constraints for energy supply specifies how electricity generation at hydropower location  $j$  is connected to the availability of the facility at this location, the installed capacity, and water released (the outflow).

$$\begin{aligned} e_{jt} &\leq PC_j \cdot \sum_{\tau=1}^t w_{j\tau} \quad \text{for } j \in J_P \quad \text{and } t=1, \dots, T, \\ e_{jt} &\leq PC_j \quad \text{for } j \in J_E \quad \text{and } t=1, \dots, T, \end{aligned} \quad (19)$$

where  $PC_j$  is the installed capacity (for electricity generation) of the hydropower facility at location  $j$ .

$$e_{j,t} \leq CR_j \times o_{jt} \quad \text{for } j \in J \quad \text{and } t=1, \dots, T, \quad (20)$$

where  $CR_j$  is the water-energy conversion ratio at location  $j$ . This constraint implies that the electricity generated at location  $j$  in period  $t$  is proportional to the amount of water released,  $o_{jt}$ .

The second set of constraints for energy supply links energy generation, distribution and consumption.

$$\sum_{k \in K_E} p_{jkt} \leq e_{jt} \quad \text{for } j \in J \quad \text{and } t=1, \dots, T. \quad (21)$$

This constraint implies that electricity supplied from location  $j$  can't be greater than the amount of electricity generated at  $j$ .

$$\sum_{j \in J} \Omega_{jk} \times p_{jkt} \leq G_{kt}^E \quad \text{for } k \in K_E \quad \text{and } t = 1, \dots, T, \quad (22)$$

where  $\Omega_{jk}$  is the yield loss of energy transmission from  $j$  to  $k$  (see Section 4.1), and  $G_{kt}^E$  is the energy gap (or shortage) at energy demand zone  $k$  in period  $t$ . This constraint indicates that the electricity supplied to a demand zone cannot be greater than the amount demanded.

#### 4.6 Flood Constraints

The flood constraint compares the water flow and the peak tolerance level at each flood zone to calculate the flood. By Section 3.3, the flooded water at flood zone  $j$  is  $f_{jt} = \max\{0, q_{jt} - MT_j\}$ . Thus, we have the following constraint,

$$f_{jt} \geq q_{jt} - MT_j \quad \text{for } j \in J \quad \text{and } t = 1, \dots, T. \quad (23)$$

This constraint is valid because minimizing the flooded water helps to optimize the objective function.

#### 4.7 Budget Constraints

The budget constraints limit the total spending on hydro supply chains (development and operations) in each year by a percentage of GDP in the past year.

$$\begin{aligned} \sum_{j \in J_p} (b_{j,1}^{HPP1} + b_{j,2}^{HPP1}) + b_1^{HPP2} + b_2^{HPP2} &\leq g_0 \cdot RA_1, \\ \sum_{j \in J_p} (b_{j,2t'}^{HPP1} + b_{j,2t'-1}^{HPP1}) + b_{2t'}^{HPP2} + b_{2t'-1}^{HPP2} &\leq g_{t'-1} \cdot RA_{t'} \quad \text{for } t' = 2, \dots, T/2, \end{aligned} \quad (24)$$

where  $RA_{t'}$  is the ration in year  $t'$ , that is, the % of GDP allocated to the hydropower sector for development and operations;  $g_{t'}$  is the real GDP in year  $t'$ .

### 5 Numerical Study

In this section, we apply the mathematical model (see Section 4) to Pakistan to generate solutions, demonstrate their potential impact and develop insights. Section 5.1 presents the real-life situation of Pakistan, and Section 5.2 provides solutions and insights.

#### 5.1 The Case of Pakistan

A map of Pakistan's existing and potential hydropower sites and major demand and flood zones is shown in Figure 3. Working closely with WAPDA, we collect related data and facts, and make the following observations.

##### **Observation 1** *Observations on the hydro supply chain of Pakistan:*

Pakistan has one major river system, the Indus, with many branches running from the world's highest mountain in the north to the Arabian sea in the south within about 1000 miles. There are 17 existing hydropower facilities, consisting of 6 storage dams and 11 non-storage barrages. Out of some 800 potential sites along the Indus river and its branches, we identified 41 locations with completed feasibility study (new construction not upgrading) and ready to be implemented. Among them, there are 13 storage dams and 28 non-storage barrages. Thus  $J = 58$ . Through WAPDA and research, we can identify all parameters, such as the latitude and longitude, cost, time, capacities, conversion ratio, etc. for all locations.

There are 19 energy demand zones that account for 90% of the country's total energy consumption (Figure 3),  $K_E = 19$ . In Pakistan, irrigation related fresh water withdrawn accounts for 93.5% of the total (World Bank 2015), thus we shall only consider farmlands (irrigation) as water demand zones. There are 15 major farming areas in Pakistan (see Figure 3) scattered across the entire country. Thus,  $K_W = 15$ .

Pakistan has uneven precipitation across the country with heavy rainfall in the northern mountain areas, which gradually decrease as we move to the southern Indus river floodplain, and then increase again close to the coast of Arabian sea. Many areas of this country experience clear patterns of seasonal rainfall between summer (April-September) and winter (October-March). In some areas, the rainy season could account for 80-90% of the annual precipitation. From the record of the government, we can estimate the external inflow at each segment of the river system.

Energy demand varies across seasons. For instance, in 2012, the summer (rainy) season consumes about 16000 MWh while the winter (dry) season consumes about 12000 MWh. The pattern is quite repetitive in the history. In the current energy mix, hydropower (from existing facilities) accounts for about 31% of the 10000 MWh consumption. Demand for energy is estimated to grow at a rate of 5-7% annually (Alter and Syed 2011). Thus, the demand for hydropower (both existing and new) includes its current contribution to the energy mix and the projected energy shortfall.

Agriculture water consumption projections are made from 2010 throughout 2025 by Pakistan Ministry of planning, development and reform. 29% of the agriculture water comes from the canal systems that connect the farmland with the hydropower facilities on the rivers (FAO 2011). Other sources of agriculture water include underground water (wells) and surface water (lakes). Thus, the demand of irrigation water for the hydropower network include its current contribution to the agriculture sector and the projected water shortfall.

Irrigation water distribution is subject to significant losses, such as seepage and technical losses. FAO statistics in general (Solomon 1998) and Pakistan studies in particular (Yu, et al. 2015) show that such losses amount to about 15% water withdrawn. Given an average traveling distance of irrigation water of about 33 miles in Pakistan, we estimate that the 100 miles yield loss is about 45% (thus,  $\gamma = 55\%$ ).

Evaporation of stored water in reservoirs causes about 40% annual loss in tropical areas (Miller and Spoolman 2009, O'Laoghaire and Himmelblau 1974). Thus, we estimate a 20% evaporation loss per period (half a year) in our study (thus,  $\eta = 80\%$ ).

We consider planning horizons of 20 years ( $T = 40$ , Padula 2015).

<b>Hydropower Facility:</b>		
$A_{j,t}$	Net external inflow to segment $j$ of the river system in period $t$	Unit: Billion Cubic Meters
$T_j$	Setup time for the hydropower facility at location $j$	Unit: period
$IC_j$	Setup cost for the hydropower facility at location $j$	Unit: million US \$
$OC_j$	Annual operating cost of the hydropower facility at location $j$	Unit: million US \$

$PC_j$	Installed capacity (electricity) of the hydropower facility at location $j$	Unit: MWh
$CR_j$	Conversion ratio of the hydropower facility at location $j$	Unit: MWh / Billion Cubic Meters
$C_j$	The storage capacity of the hydropower facility at location $j$	Unit: Billion Cubic Meters
$X_{j,j'}$	Matrix of immediate upstream locations	Binary
<b>Power Supply:</b>		
$\omega$	% yield in power transmission per 100 miles	95.5%
$\Omega_{jk}$	Transmission yield in % between location $j$ and demand zone $k$	$\Omega_{jk} = \omega^{D_{jk}}$
$G_{kt}^E$	Energy gap at demand zone $k \in K_E$	Unit: MWh
<b>Water Supply:</b>		
$\gamma$	% yield in irrigation distribution per 100 miles	55%
$\Gamma_{jk}$	Water distribution yield in % between location $j$ and demand zone $k$	$\Gamma_{jk} = \gamma^{D_{jk}}$
$\eta$	% yield by evaporation for stored water in reservoir per period	80%
$r_j$	% of total flow into location $j$ that can be withdrawn for usage	31%
$G_{kt}^W$	Water gap at demand zone $k \in K_W$ in period $t$	Unit: Billion Cubic Meters
$Y_{j,k}$	Water distribution feasibility matrix	Binary
<b>Flood:</b>		
$MT_j$	Peak tolerance flow in one period at location $j$	Unit: Billion Cubic Meter
<b>Miscellaneous:</b>		
$RA_{t'}$	Ration in year $t'$ : i.e. % of GDP	Unit: %
$\beta_{t'}$	Discount factor in year $t'$	Unit: %
$D_{jk}$	Distance between location $j$ and demand zone $k$	Unit: 100 miles
$M$	A real number large enough for the Big-M method	N/A

Table 4: Parameters for Pakistan's hydro supply chain.

Table 4 specifies the model parameters for Pakistan. Note that the hydropower setup cost,  $IC_j$ , includes cost of transmission line and grid station that connect the hydropower facility to the nearest transmission system. It also includes the cost of water passages (or pumping station) that connect the facility to the nearest canal system. All other parameters of hydropower facilities are extracted from feasibility studies and government research reports. Pakistan's current transmission systems use the alternating current (AC) technology (National Transmission and Despatch Company 2014) and will continue to use this technology in the foreseeable future (Weedy, et al. 2012). Based on the voltages used in Pakistan, we conservatively estimate the yield loss per 100 miles,  $(1 - \omega)$ , to be

4.5% (Hurlbut 2012).

The energy and water gaps (shortages) at each demand zone are calculated based on the government's estimate of future demand and items 4-5 in Observation 1.  $r_j$  is determined by the general statistics of water withdrawn at hydropower locations (Barber 2009). The water distribution feasibility matrix,  $Y_{j,k}$ , is determined by Assumption 1 where  $Y_{j,k} = 0$  if the water demand zone  $k$  is upstream of location  $j$ . The  $MT_j$  can be estimated by the average flow per period at location  $j$  plus a location dependent buffer (from government's statistics).

Our empirical study (multiple linear regression) of Pakistan's data from year 1977 to 2011 shows a strong dependence of the real GDP on energy consumption, irrigation water and flooded water ( $R^2 = 0.999$ ). We estimate  $a_1 = 12.224$ ,  $a_2 = 135.439$ ,  $a_3 = -71.196$  with p-value of  $1.9E-11$ ,  $2.66E-06$  and  $0.008$  respectively. We select 2011 as the starting year ( $t = 0$ ) with a GDP  $g_0 = 133,000$  (in million \$), a peak demand (summer peak load) of 16,000 MWh and an energy gap of 6,000 MWh (Kessides 2013). The initial condition  $P_{j,k,0}, P_{j,k,-1}, u_{j,k,0}, u_{j,k,-1}, f_{j,0}, f_{j,-1}$  are determined by starting year 2011's data.

## 5.2 Solutions, Impacts and Insights

In this section, we apply the mathematical model to the case of Pakistan and compare the optimal solutions to two heuristics on metrics such as net GDP (GDP less investment in hydropower sector, for economic growth), energy gap (for energy security), water gap (for irrigation), and flooded water (for flood control). We provide insights on how to build up a hydropower network under economy-dependent budget, and demonstrate the value of the supply chain perspectives. The first heuristic (H1) sorts and constructs the hydropower sites in the increasing order of the setup cost per unit of installed capacity as long as the budget allows. The second heuristic (H2) sorts and constructs the hydropower sites in the decreasing order of the installed capacity. These heuristics reflect the approaches used in practice by countries such as Pakistan and Congo (Sections 1.3 and 1.5). To ensure fairness in comparison, we apply the same procedure in the optimal solutions and the heuristics to optimize the flow control and water/power distribution decisions. Thus, the performance difference among them comes from the strategic decisions on the selection and sequence of the sites.

We consider scenarios under the following combinations of parameters: budget ration from 0.1%, 0.2%, to 0.6% of the real GDP (consistent to Pakistan's budgetary practices on water and power development, see, e.g., Public Sector Development Programme 2015-16 by Ministry of Planning, Development and Reform), a planning horizon of 20 years (40 periods), an energy demand growth rate of 5%, and a water demand growth rate of 4.08% (Mustafa, Akhter, Nasrallah 2013).

The mathematical model leads to a large-scale multi-period mixed integer program with 11,188 constraints, 76,357 continuous variable and 1,182 binary variables. The mathematical program is solved by Gomory cutting planes method and implemented by a code written in Python version 2.75 and Gurobi Solver version 6.5. We cannot always obtain the optimal solution because of the model complexity, so we accept suboptimal but best solutions found if the values of their objective functions are within 2% of those of the optimal solutions. The computation time ranges from a few minutes to about two hours. All computations are done on a desktop computer with an Intel Xeon 2620 2.0 GHz and 36 GB RAM.

### A Representative Example.

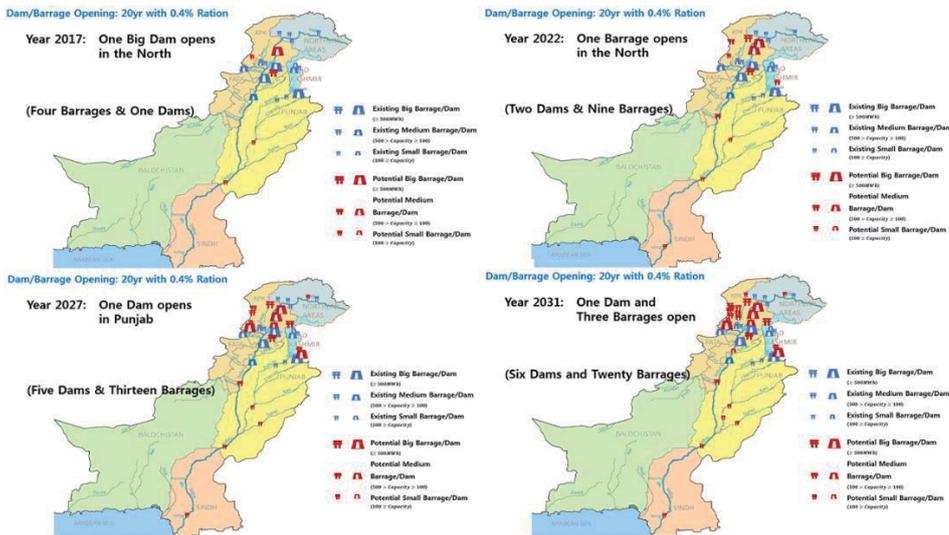


Figure 7: The optimal solution on the opening sequence of potential hydropower sites for the scenario with a budget of 0.4% GDP.

To develop insights on the optimal expansion of a hydropower network, we first examine the example of 0.4% budget ration in detail. In this example, the optimal solution first opens barrages of different capacities in the south (Sindh province) and north (Punjab province) but not far north, close to the major power and water demand zones in these provinces. Then it opens a large dam ( $\geq 500$  MWh) in the north but not far north (Tarbela, near the capital city, Islamabad), and a few more small ( $< 100$  MWh) and medium ( $\geq 100$  MWh but  $< 500$  MWh) barrages around the country. This is followed by a series of openings of small, medium and large sites (both dam and barrage) scattered from northeast to northwest, from north to south, and from one branch to another of the Indus river. Although the potential sites of the largest capacity (also the lowest unit cost) are concentrated in the north and far north areas of the country, the optimal solution does not pick them exclusively, but blend them with small and medium sites from other areas. In this example, totally 26 new hydropower sites are opened over the planning horizon, where small sites account for a greater percentage, 40%, in the mix of the first 10 years than the second 10 years, 31.25%. Over different rations, our computation shows that the median of the percentages of small hydros in the mix of the first 10 years is 42.22%, higher than the corresponding median, 30.63%, in the mix of the second 10 years.

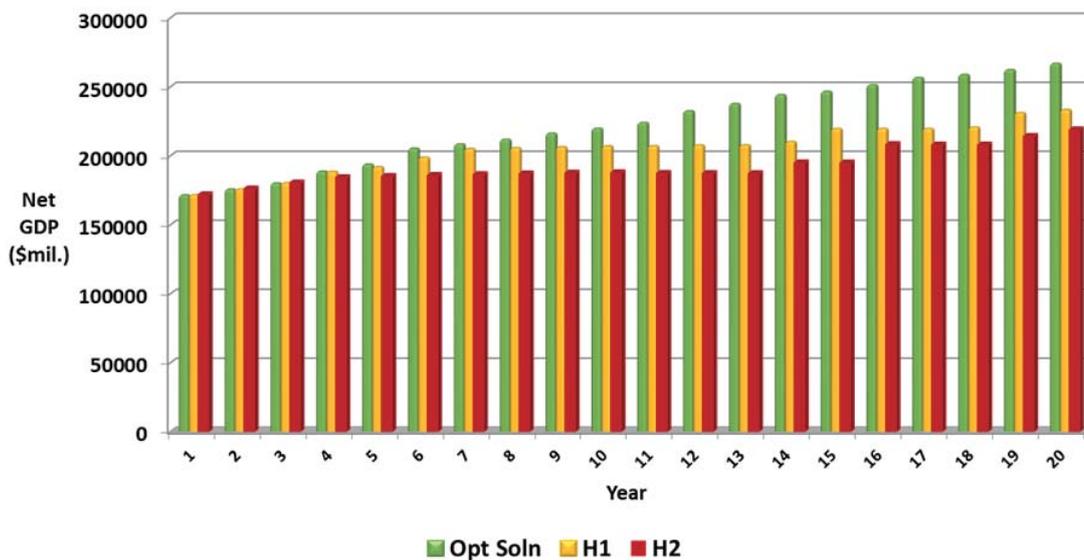


Figure 8: Optimal solution vs. heuristics. The x-axis is on time (in year). 0.4% budget ration.

The optimal solution demonstrates importance of the supply chain perspectives. First, the yield losses in distribution play a greater role than economies of scale in site selection as the optimal solution spreads out the sites (rather than concentrating them) so that the demand zones can be served better and more evenly over time. Second, the higher percentage of small hydros in the first 10 year than the second 10 years indicates that we should build more small hydros early on to quickly boost economy and improve financial status; with more funds being available, then we can build more medium and large hydros. The solution also shows that dams and barrages are complementary, and a hybrid strategy is preferred to strategies focusing exclusively on one type, to achieve, simultaneously, development goals in energy, irrigation and flood control.

In comparison, for the same example, H1 starts with a few largest sites in the north and far north, which exhausts all the budget in the first few years. Only after they are done (thirteen years after), the government then has the money to work on a few smaller sites with higher unit cost. This is followed by other large and medium sites from diverse locations which open up gradually. In this heuristic, totally 11 new hydropower sites are opened in the planning horizon. H2 opens fewer new sites (7 total) almost all towards the end of the planning horizon because it focuses on the largest sites (which cost the most and require the longest time).

Because a majority of potential sites locate in the north, hydropower is primarily supplied to the north, the Punjab industry zone, the largest demand zone of the country. Some hydropower is supplied to the south, the Karachi commerce zone, but insufficient to significantly reduce the energy gap even if it is achievable in the north. Similarly, farmland in the north trends to get more irrigation water earlier than that in the south.

To quantify the impact of the model, we compare the optimal solution and the heuristics on four metrics: net GDP (Figure 8), % energy demand gap, % water demand gap, and flood (Figure 9).

As we can see, the optimal solution outperforms the heuristics quite significantly by boosting the economy stronger (Figure 8), and improving the performance of all three sectors - energy consumption, irrigation and flood control (Figure 9). Specifically, in this example, the optimal solution can reduce the energy gap by 10-20% relative to the heuristics in most of the periods. The optimal solution can reduce the water gap to zero while the heuristics constantly keep a 20% to 40% water gap. Finally, the optimal solution can reduce flood by about 10% in many periods relative to the heuristics.

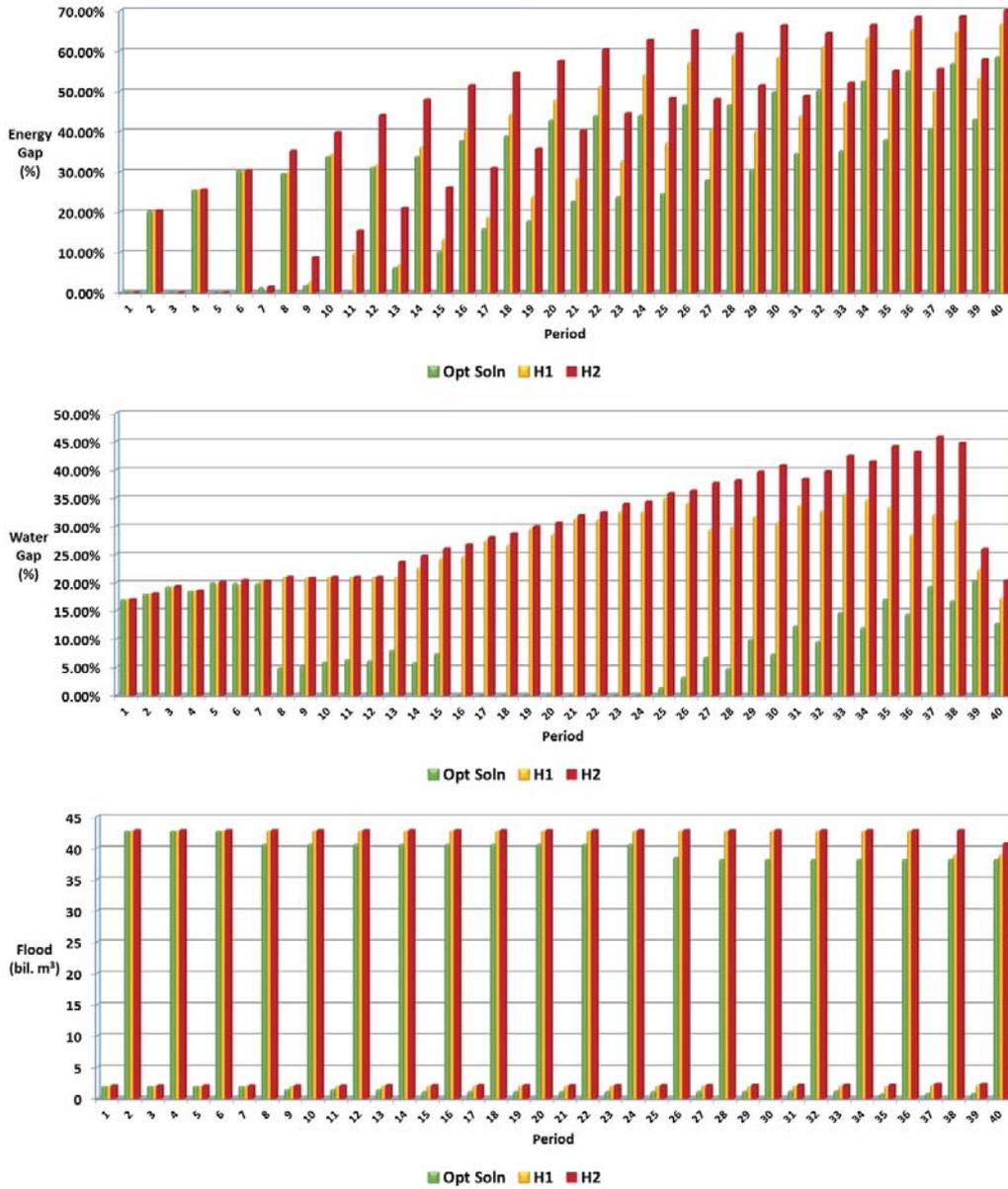


Figure 9: Optimal solution vs. heuristics. The x-axis is on time (in period). 0.4% budget ration.

### The Impact of Budget

The budget ration can have an impact on the optimal solution. For different rations, although the optimal solutions always spread out new sites close to demand zones, the mix of size and type can change. Specifically, as the budget ration increases, it is optimal to build a higher percentage of dams and a smaller percentage of small hydros in the mix (see Figure 10).

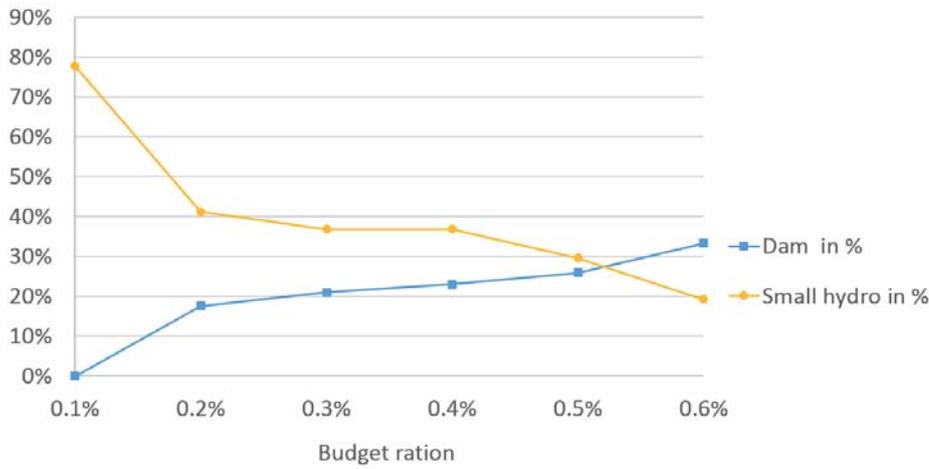


Figure 10: The impact of budget ratios on the optimal mix: the % of small hydro and % of dam for the planning horizon.

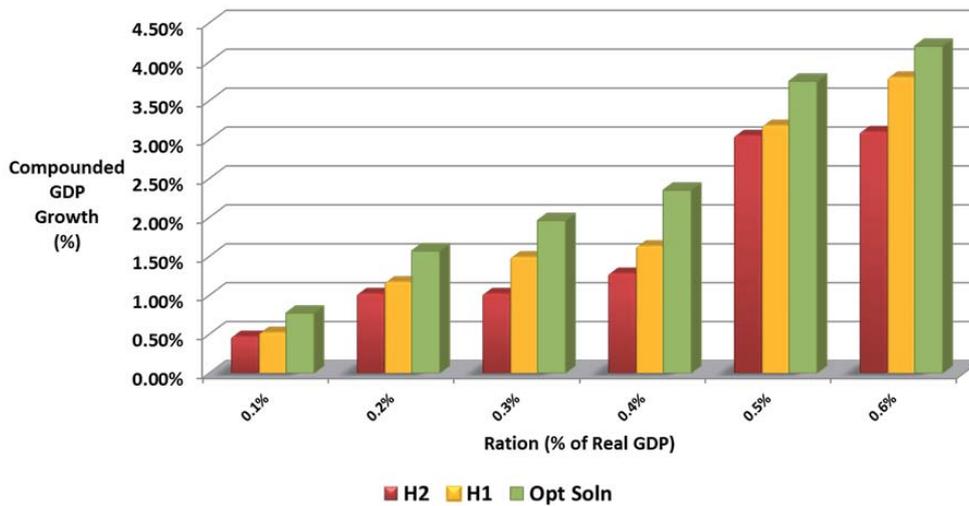


Figure 11: The compounded GDP growth rate for the optimal solution, heuristics 1 and 2 for various budget ratios.

To study the impact of the budget ration on the performance, we plot the compounded GDP growth rate for the optimal solution and the two heuristics for different budget ratios from 0.1% to 0.6% (Figure 11). The figure shows that although the optimal solution always outperforms the heuristics on GDP growth rate, it makes the greatest difference when the budget is neither too tight nor too generous. Intuitively, if the budget is very tight, it allows little flexibility for the optimal solution to improve; if the budget is very generous, the efficiency as achieved by the optimal solution becomes relatively unimportant as funding is abundant.

### Insights and Practices

The solutions provide useful insights for developing countries to build up their hydropower network. Intuitively, if we can split the country into multiple regions (e.g., close to different major demand zones) where each region has multiple potential sites with different type and size, then it is generally more preferable to spread out sites to these regions than concentrating them all in one region. It may also be preferable to first build small hydros then build medium and large ones. If a higher budget is available, we may build more dams and more medium and large

hydros in each region.

The insights help us answer the questions raised in Section 1.6. First, neither the strategy of many small sites nor that of a few large sites is the best, the optimal solution is hybrid as it combines large and small sites in ways that depend on the budget and time. Second, spreading out sites close to demand zones (if possible) may be better than concentrating them in the geologically ideal areas because location flexibility (or yield losses) can be more important than the economies of scale in hydropower site selection. Finally, storage dams and non-storage barrages are complementary but the optimal mix depends on budget.

The insights allow us to assess the effectiveness of the practices in countries like China and Pakistan. China in early 1950s' had little money and technology. To combat the severe issues of water, food, energy and flood, China built a huge amount of small hydros around the country in its first 5-year plan (Peng and Pan 2006). Intuitively, this is a correct approach given the tight budget and significant yield losses. These 90,000 some small hydros served the vast rural areas and laid the foundation for future economic growth. Pakistan, on the other hand, took a different approach by focusing mainly on large hydros in concentrated areas. As its experience shows, the approach was far from optimum and couldn't resolve the periodical flood and drought. Most recently, Pakistan government started to build barrages closer to major farmland in the southern plains. However, it remains uncertain as to how the government plans to further expand the hydropower network in the future.

## **6 Conclusion**

The interconnected issues of water, energy, food and flood lie at the center of the sustainable development of economy and society for many developing countries. Hydropower development can be an ideal solution as it is not only abundantly available in many of these countries but can also address all these issues in the same time. However, these issues can be conflicting and thus how to effectively develop hydropower network under limited financial resource to address the nexus of water, energy, food and flood poses as a substantial challenge.

In this paper, we construct an integrated mathematical model that bridges the water resource development literature and energy system planning literature to capture the nexus and unique features of hydropower development in developing countries. Built on location optimization theory and a cascading model of multi-stage water flow, the model can coordinate the synergy and balance the conflicts of the diverse development goals, and maximize the overall benefit. Applying the model to the real life situation of Pakistan, we demonstrate the potential of the model in improving energy consumption, irrigation and flood control simultaneously relative to common practices, and thus contributing to the sustainable development of the economy and society. The model can be applied to other developing countries with rich hydro reserves, such as India, Turkey and Kenya, that are facing similar challenges (Yukseka, et al. 2006, Kenya Ministry of Energy 2012).

This work can be extended in a number of directions: First, a larger scale study of Pakistan with more potential sites and higher budget can be conducted for real-life implementation. Our current study conforms to Pakistan's budgetary practices and is limited to most ready hydropower sites. Second, the mathematical properties of hydro supply chains can be explored to enable more efficient solution algorithms. Third, we ignore political issues in hydropower network expansion with the objective of developing the optimal solution free of politics to serve as a benchmark. For a solution to be implementable, however, politics should be considered to ensure not only effectiveness but also political correctness. Finally, we assume that all other energy generation sources run their businesses as usual to focus on hydropower planning. It would be interesting to explore the synergy among different energy sources and to optimize the energy mix (or portfolio) as a whole.

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# Drivers for Green Supply Chain Management: Priorities and Impact from Organizational Theory Perspective

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## ABSTRACT

This study aims to identify and prioritize drivers affecting green supply chain management (GSCM) implementation for achieving sustainable development goals in the electronics industry in Thailand. The research examines relationship between priorities of the drivers, based on evaluation by three different groups of experts (decision makers). In this study, the applicable drivers affecting the firms' sustainability (i.e. economic, social, and environmental performance) through GSCM practices are obtained using fuzzy Delphi method, viewed through organizational theory perspective. These drivers are then prioritized by fuzzy AHP-based group decision making, using the views of three groups of experts. The Spearman rank correlation is used to determine the level of agreement between the rankings among the three groups. This study explores the most important drivers especially for the 'green' start-ups with a sustainability-driven organizational strategy. It is noted there is considerable consistency between the rankings, leading to strong support that the ranking is applicable across three groups of experts. A set of recommendations are made for stakeholders to enhance the success of implementing GSCM towards sustainability targets. Moreover, it is expected that these findings be useful in efforts to improve sustainability performance of the electronics industry, and will be useful to international electronics firms seeking a share in the Thai markets.

**KEYWORDS:** Sustainability, Fuzzy Group Decision-Making, Correlation Analysis

## 1. INTRODUCTION

With increasing competitive pressures and environmental concerns over the last couple of decades, green supply chain management (GSCM) has been gaining growing interest among researchers and practitioners of operations and supply chain management (Srivastava, 2007; Sarkis, 2012; Perotti et al., 2012). Companies have recognized that GSCM can create sustainable competitiveness (Solér et al., 2010; Hu and Hsu, 2010) and lead to a sustainable development (Muduli and Barve, 2011; Zhou, 2009).

Since GSCM implementation is effectively influenced by several strategic drivers, it is essential that drivers that motivate and initiate implementation and adoption of GSCM practices be identified first. In addition, it is important that these drivers be prioritized for decision making process and policy setting. Identifying and prioritizing drivers will enable successful implementation of GSCM, especially for the 'green' start-ups with a sustainability-driven organizational strategy.

However, there is still no strong theoretical basis on which GSCM drivers contribute the most for a sustainable development. Besides, previous studies have indicated that the drivers of sustainability are complex in nature (Shore, 2013). No single theory seemed adequate to explain the complex phenomena to analyse the sustainable drivers. Therefore, the multiple theories must be applied, resulting in better identifying a set of drivers of sustainability and developing a more comprehensive analysis of (sustainable) competitiveness (Sirikrai and Tang, 2006).

Therefore, this study attempts to answer the following two questions: (1) What are the drivers affecting GSCM implementation of the sustainable development goals in the electronics industry in Thailand, and how varying the relative importance of these drivers? (2) Are there significant correlation between the GSCM driver rankings given by the three different groups of experts (including the senior managers, middle managers, and consultants)?

Thus, this study is grounded on three organizational theories of sustainable competitive advantage in which these theories can lead to sustainable development, including the resource-based view (e.g. Barrutia and Echebarria, 2015; Barney, 1997; Epelbaum and Martinez, 2014), the relational view (Touboulic and Walker, 2015; Saleh et al., 2014), and the institutional theory (Stål, 2015; Wilhelm et al., 2016; Moore, 2013; Zhu et al., 2013; 2016). The study then applied these theoretical perspectives to help identify drivers for sustainability initiatives and develop a theoretical framework that leads to explore the most significant drivers. Furthermore, the applicable drivers are prioritized by a fuzzy AHP-based group decision making according to the views of three groups of experts including the senior managers, middle managers, and consultants. So, the obtained priorities of GSCM drivers can be used for setting related policies.

## 2. LITERATURE REVIEW

### 2.1 Green supply chain management

Green supply chain management is the intra- and inter-firm management of the upstream and downstream supply chain concentrated on minimizing the overall environmental impact of the forward and reverse flows of the supply chain (van Hoek, 1999; Klassen and Johnson, 2004; Zhu et al., 2008), while creating economic value, and lowering (energy) costs of production of the firms (Zhu and Sarkis, 2004; Vachon and Klassen, 2008; Kirchoff, 2011).

In electronics industry in Thailand, using as a case study, an environmental awareness has become an important issue due to the present global agenda of sustainable development. Since 1st July 2006, new electrical and electronic equipment sold in the European Union (EU) market must comply with the Restrictions of the use of Hazardous Substances (RoHS) directive.

In recent years, like other countries, electrical and electronic equipment manufacturers in Thailand exporting products into the EU have introduced GSCM into their operations, as an effort to ensure compliance with the requirements of the RoHS directive and to subsequently gain a competitive position in the EU market (Zhu et al., 2010). Many leading international electrical and electronic equipment manufacturers, including Dell, HP, IBM, Motorola, Sony Panasonic, NEC, Fujitsu, and Toshiba have already established their green supply chains (Zhu and Sarkis, 2006; Lee, 2008).

The GSCM practices in Thailand are still in early stage and are new to most industries and operations managers. Thus, it would not be easy for them to adopt GSCM practices with the aim of promoting sustainable development. In this regard, both sustainable development and GSCM drivers are essential part of overall discussion, leading to identifying GSCM drivers, using experts' inputs and opinions.

## 2.2 Sustainability performance

The most widely used interpretation of sustainability is described in three different areas: environmental, social and economic dimensions (Eklington, 1994). These three areas are also known as the 'triple bottom line.' Kocmanová and Dočekalová (2011) defined 'sustainability of businesses and sustainable performance' as an integration of environmental, social and economic performance. Various research studies have documented a range of key performance indicators across these three dimensions, providing different perspectives including impact on performance and methods for assessing sustainability from industry perspective (Green et al., 2012).

Environmental performance is a measure to reduce the impact of supply chain management activities on the environment. Environmental performance refers to the extent to which an organization improves outcomes related to pollution control and environmental management (Zhu and Sarkis, 2004; Matos and Hall, 2007; Montabon et al., 2007; Pullman et al., 2009; Jacobs et al., 2010; Yang, 2013). Environmental performance indicators for evaluating an environmental performance taking into account the effect upon an environment of business activities, processes, goods and services, consist of the following categories: material consumption, fuel usage, emissions, and waste created.

Economic performance is the extent to which an organization improves operational, market, and financial outcomes (Narasimhan and Kim, 2002; Flynn and Flynn, 2004; Menor et al., 2007; Kristal et al., 2010; Yang, 2013). Economic performance indicators which are used for assessing sustainability consist of the following categories: cost reduction, market share growth, and profit increase.

Social performance is the extent to which an organization improves employee- and community-oriented outcomes (Rao and Holt, 2005; Yang, 2013). Social performance indicators for examining social impacts of a firm on its local and wider community for sustainable development are generally 'internally' focused towards such aspects as employee safety, health and security and job satisfaction levels.

It can be seen from broader aspect of sustainable performance that GSCM practices can yield different levels of sustainable performance, depending on selection and implementation of different GSCM practices and drivers influencing the overall adoption in supply chains.

## 2.3 GSCM Practices Implementation

In spite of the increased interest and emerging body of knowledge on GSCM, there is still lack of unified framework of green practices (Diabat and Govindan, 2011; Wu et al., 2011; and Laosirihongthong et al., 2013). Based on previous exploratory research (e.g. Diabat and Govindan, 2011; Wu et al., 2011; Zhu and Sarkis, 2004; Rostamzadeh et al., 2015; Ninlawan et al., 2010), GSCM practices can be conceptualized into six different dimensions of practices including eco-design, green purchasing, green logistics, green manufacturing and remanufacturing, environmental management, and reverse logistics.

Eco-design (or green design) refers to a design using life-cycle analysis and environmentally conscious design that requires the consideration of certain elements in product design including the reduction or elimination of hazardous substances, reuse, recycling, remanufacturing, and efficiency of resources (materials and energy) during the use of products (Mudgal et al., 2009; Zhu et al., 2008; Eltayeb et al., 2011; Lin, 2011). Green purchasing refers to the purchase of environmentally friendly products and avoiding products that harm the environment (Joshi and Rahman, 2015). Green purchasing initiatives include the selection of appropriate materials and suppliers, verification audits of suppliers to ensure compliance with ISO14000, OHSAS18000, RoHS etc., supplier environmental auditing, and establishing environmental requirements for purchased items etc. (Chien and Shih, 2007; Zhu et al., 2008; Ninlawan et al., 2010; Eltayeb et al., 2011; Chan et al., 2012).

Green logistics refers to the logistics activities that have the goal of reducing the pollution of the environment and the resource consumption. Green logistics initiatives include route optimization, packaging optimization, use of recycled packaging (redesigning packaging to use less material), and total carbon footprint reduction (carbon emissions reduction). Green manufacturing refers to a method for manufacturing that minimizes waste and pollution through product and process design (Maruthi and Rashmi, 2015). According to Nikbakhsh (2009), green manufacturing includes activities such as reducing, and recycling; while remanufacturing includes reusing, and product/material recovery. Nikbakhsh (2009) also noted that green manufacturing and remanufacturing requires inventory management, production planning, and scheduling besides usual planning due to varying and unknown amounts of returned products for recycling.

Environmental management refers to sustainable management approaches that aim for engaging in green processes and practices in order to reduce the environmental impact of the firm's activities (Gotschol et al., 2014). Its initiatives include establishing environmental management systems (e.g. the ISO 14001 certification, the OHSAS 18001 standard and waste management that includes source, pollution prevention, and disposal), integrating environmental strategies and business strategies, and environmental

auditing (Zhu et al., 2007). Reverse logistics refers to the process of planning, implementing, and controlling the efficient, cost effective flow of materials, parts, products and related information from the point of consumption to the point of origin for the purpose of recapturing value or proper disposal (Rogers and Timbnn-Limbke, 1999). Reverse logistics has four stages: collection, inspection, preprocess and location and distribution of end-of-life materials, parts, and products (Srivastava, 2007) as well as storage, reprocessing (including recycling, reusing, repairing/ refurbishing, etc.), and/or disposal (Nikbakhsh, 2009).

#### *2.4 Drivers for adopting GSCM practices*

There are many ways to classify the drivers affecting the implementation of GSCM, proposed by different authors (Walker et al., 2008; Diabat and Govindan, 2011; Trowbridge, 2001; Somsuk et al., 2013; Dhull and Narwal, 2016) and classifying them into groups based on the research goal of the papers. In this paper, the categorization of drivers is determined from the (theoretical) linkages between the theory-based drivers and sustainability performance. Thus, we classify the drivers into three groups: (1) the internal drivers of GSCM practices found in the RBV theory encompass the firm-strategic resources and capabilities (Lee, 2008; Sarkis et al., 2011; Zhu et al., 2008); (2) the relational drivers consist of inter-firm resources and routines found in the RV; and (3) the external drivers (pressures) as institutional drivers found in the institutional theory (Speziale and Klovienè, 2014). This will lead to a concise answer to our main research question and will lead to reasonable conclusions and recommendations. Moreover, the issue of sustainable driver identification has been rarely studied in the Thailand context. However, understanding what drives firms adopt (or implement) GSCM practices for sustainability from Thai expert opinion, supported by organizational theoretical perspective will allow policy makers to build a suitable environment and provide incentives for the adoption of these GSCM initiatives in order to making firms in supply chain more sustainable.

#### *2.5 Organizational theory and GSCM Drivers*

The literature on strategic management indicates that the resource-based view (RBV), relational view (RV), and institutional theory (INT) have been perceived as influential theoretical frameworks to explain a firm's competitive advantages (Moore, 2013; Wilhelm et al., 2016; and Zhu et al., 2016).

The RBV explains that a sustainable competitive advantages stems from the valuable, firm-specific resources (and capabilities) that are imperfectly mobile and imperfectly imitable (Barney, 1991). The term 'resources' refers to tangible and intangible assets, employee- and firm-level capabilities, organizational processes and attributes, information, knowledge etc., which are controlled by a firm and its employees, and positively affect its efficiency (Barney, 1991; 2001). According to Barney (1997), in order to provide a sustainable competitive advantages and, thereby, superior performances, a resource must be valuable, rare, imperfectly imitable, and non-substitutable (VRIN) attributes.

On the other hand, the RV emphasizes that competitive advantages derives not solely from a firm's unique resources but also from the strategic relational resources (or capabilities) generated from collaboration between firms (Dyer and Singh, 1998; Lavie, 2006). According to Dyer and Singh (1998), there are four potential sources of inter-organizational competitive advantages: Relation-specific assets, knowledge-sharing routines, complementary resources, and effective governance. Furthermore, the relational view can be regarded as an extension of the RBV with a focus on inter-firm relationships and routines – for example, knowledge or capabilities generated by inter-firm relations in the supply chain which are seen as valuable resources (Lavie, 2006).

Institutional theory as a lens to understand the drivers of green supply chain initiatives helps us to understand how institutional pressures force firms to adopt organizational practices to gain legitimacy (Seo and Creed, 2002; Lai et al., 2006) or even to gain sustainable development (Bansal, 2005; Berrone et al., 2007). According to Zsidisin et al. (2005), there are three forms of institutional isomorphic pressures: – coercive pressures, mimetic pressures and normative pressures which may compel or drive firms to adopt GSCM practices. Mimetic pressures occur due to uncertainty in the environment that encourages firms to imitate (Zsidisin et al., 2005) GSCM practices of successful competitors in industry to repeat their successful path for improved competitiveness. Coercive pressures such as government pressure or regulatory, exerted on firms by other more powerful organizations (e.g. government, multinational corporations) may force firms to implement GSCM practices concerning their safety and environmental behavior in order to be perceived as more legitimate (Vykoukal et al., 2011). Normative pressures exerted by social pressures (e.g. society and customers to use the resource efficiently and not to harm) cause firms to conform to a set of norms or social legitimacy or standards widely accepted in the industry.

In this study, the RBV, RV, INT are considered as a grounded theory to develop the drivers and the model. Thus, internal drivers refer to the drivers that are generated by a firm's internal resources with characteristics of value, rarity, inimitability and non-substitutability (VRIN). They can be divided into many groups including the organizational resources (e.g. systems, competence, culture, routines, policies, and business processes), human resources, technological resources, and the financial resources (Somsuk et al., 2012). Relational drivers refer to the drivers that are generated by inter-firm relationships (e.g. relationships or collaborations suppliers and customers) as proposed by the relational view (Lado et al., 1997) and external drivers refer to the coercive pressures, mimetic pressures and normative pressures.

Such classification of drivers is necessary not only for better understanding the theory-based drivers (i.e. resource-based, relational, and institutional drivers) in order to help develop strategies for effectively managing the firm's strategic resources, the inter-firm relationships and routines, and the external factors but also for developing a theoretical framework and a hierarchical decision-making model for ranking the drivers that affect the sustainable performance.

### **3. METHODOLOGY**

The research methodology consists of four stages and is briefly outlined. The first stage is to review the literature on GSCM practices, drivers, and performance measures towards sustainability, and then, based on literature review, preliminarily identify the potential drivers of sustainability through the lenses of the RBV, RV, INT perspectives. By applying these theories, a set of potential drivers of sustainability are derived from characteristics identified by RVB, RV and INT theorists, so, identifying these drivers is

theoretically well grounded. The second stage is to screen out inapplicable drivers by applying fuzzy Delphi method. To identify the applicable drivers affecting the sustainability of competitive advantage through GSCM in electronics industry in Thailand, 'it is necessary to verify the appropriateness of the factors (or drivers) extracted from related literature' (Hsu et al., 2015, p.30) to determine whether they are appropriate or applicable for GSCM implementation in the Thailand's electronics industry context. Thus, this study attempts to evaluate the appropriateness of the extracted theoretical drivers before determining their relative importance. The fuzzy Delphi method is applied to ensure the appropriateness of the drivers extracted from the literature in order to screen drivers and to help identify appropriate/ applicable GSCM drivers for the context of the electronics industry in Thailand. The third stage is to determine the weights of drivers by using fuzzy AHP method. A hierarchical model is developed based on the applicable drivers and then these drivers are prioritized using fuzzy AHP approach. The fourth stage is to examine the relationship between the rankings which obtained from different groups of experts by using the Spearman rank correlation test. Moreover, the findings are also formulated into a set of comprehensive recommendations, which will help to enhance the sustainable development of GSCM in electronics industry in Thailand.

#### 4. RESULTS

##### 4.1 Drivers through the lenses of the organizational theories

We generalized and categorized fourteen possible drivers of sustainable development under three categories including the internal (RBV-based), relational (RV-based) and external (INT-based) drivers. Categorization is based on the relevant literature on drivers for the implementation of GSCM and review of GSCM drivers through the lenses of the organizational theories. In this context, drivers of sustainability are derived from characteristics identified by RVB, RV and INT theorists, so, identifying these drivers is theoretically well grounded.

Based on the three organizational theories discussed, we identify fourteen possible drivers affecting the implementation of GSCM practices in creating firms for sustainability. They include (i) Top management support, waste/pollution reduction, cost reduction, quality improvement and employee involvement/motivation, extracted from RBV perspective, (ii) Commitment with suppliers, commitment with customers, knowledge sharing in supply chain and company's green image/reputation, extracted from RV perspective, and (iii) Government, customer, competitor, society and supplier pressures, extracted from INT perspective.

##### 4.2 The fuzzy Delphi results

By using the fuzzy Delphi method, the theory-based drivers are screened to determine whether they are applicable for the context of the electronics industry in Thailand. An anonymous questionnaire was prepared and twelve experts consisting of two senior managers, six middle managers, and four senior consultants in ISO 14001 with more than ten years experience in implementing GSCM practices were asked to evaluate the appropriateness/applicability of each theoretical driver. A convergence of their opinions was obtained, and twelve applicable drivers were extracted. In this research, we subjectively set 8 (80% of the assessment scale of 10) as the threshold value for all categories by the 80/20 rule. The results are shown in Table 1, and the drivers with the consensus significance value,  $G_i$  greater than the threshold of 8 are selected to be applicable drivers for GSCM implementation towards sustainability in Thai expert perspective.

**Table 1.** Extraction results of the theory-based drivers

Categories	Theory-based drivers	$G_i$	Analytical results
Internal (RBV-based) drivers	Top Management Support	8.73	Applicable
	(Waste) Pollution Reduction	8.42	Applicable
	Cost Reduction	8.43	Applicable
	Quality Improvement	6.56	Inapplicable
	Employee Involvement / Motivation	8.08	Applicable
Relational (RV-based) drivers	(Collaboration/) Commitment with Suppliers	8.20	Applicable
	(Collaboration/) Commitment with Customers	8.40	Applicable
	Knowledge Sharing in Supply Chain	8.33	Applicable
	Company's Green Image and Reputation	8.04	Applicable
External (INT-based) drivers	Government Pressures	8.44	Applicable
	Customer Pressures	8.07	Applicable
	Competitor Pressures	8.15	Applicable
	Society Pressures	8.05	Applicable
	Supplier Pressures	7.33	Inapplicable

The twelve applicable drivers are extracted under three categories including the RBV-based, RV-based and INT-based drivers. In this case, RBV-based drivers are top management support, pollution (waste) reduction, cost reduction, and employee involvement/motivation. RV-based drivers include collaboration with suppliers, Collaboration with customers, knowledge sharing in supply chain, and company's green image and reputation. INT-based drivers are pressures of government, customer, competitor and society. In order to prioritize these applicable drivers, the fuzzy AHP method is used.

4.3 The fuzzy AHP results

A hierarchical model is formed based on the applicable drivers and then these drivers are prioritized using fuzzy AHP approach. First, the selection of experts is crucial and should be well-considered (Laws et al 2004). In this study, three stakeholder groups are identified as experts and include the senior managers, middle managers, and consultants.

At the beginning, in this decision making process, it is assumed that all the stakeholder groups have equal importance. Equal weights (33.33%) were assigned to each stakeholder group. However, it is also important to note that all stakeholder groups which have ‘experience in practical application/ implementation’ are the ‘experts’ but the representatives of stakeholder groups are not necessarily ‘experts’ if they lack experience in practical application/ implementation.

In this study, the middle and senior managers in electronics industry in Thailand with more than ten years experience in implementing GSCM practices as well as Thai senior consultants with more than ten years experience in ISO 14001-based Environmental Management System (EMS) are preferred as experts for the collection of their opinions and concerns. Chen et al., (2009) argued that the number of experts should be large enough to assure multiple perspectives, and small enough to make the research manageable. Hence, twenty-seven experts (8 senior managers, 10 middle managers, and 9 consultants) were selected. This is a quite balanced representation of all groups of experts, with multiple perspectives to be incorporated in the prioritization process (Hoffman, 1982). The procedure of fuzzy AHP approach to calculate weights of the drivers is outlined as follows:

Developing a hierarchical structure for prioritizing the drivers: We propose a 5-level analytical hierarchy process model as shown in Figure 1 to prioritize the main drivers of sustainable development for GSCM practices, based on the relationships between GSCM drivers, practices and the three fields of sustainable development performance within the electronics industry in Thailand. From Figure 1, the level 1 expresses the overall goal of this study, which is (the prioritization drivers in) GSCM implementation to gain sustainable competitive advantages or performance. The level 2 presents the three fields of sustainable development performance, in which these performances can be thought of as sub-goals. The level 3 presents the six of GSCM practices. The level 4 presents the three of driver categories from three theoretical perspectives. The lowest level features the drivers in each category.

Establishing a fuzzy judgment matrix (or a pairwise comparison matrix): The fuzzy AHP-based questionnaires were provided to collect information from the experts. Each expert was asked to assign linguistic terms based on his/her subjective judgment, to the pairwise comparisons by asking which one of two elements is more important and how much more important it is with respect to their upper level. In decision-making, each expert gave his/her preference on the elements using fuzzy judgment matrix. After getting the answers from experts in linguistic terms, these linguistic judgments are then converted to triangular fuzzy sets as defined in Table 1.

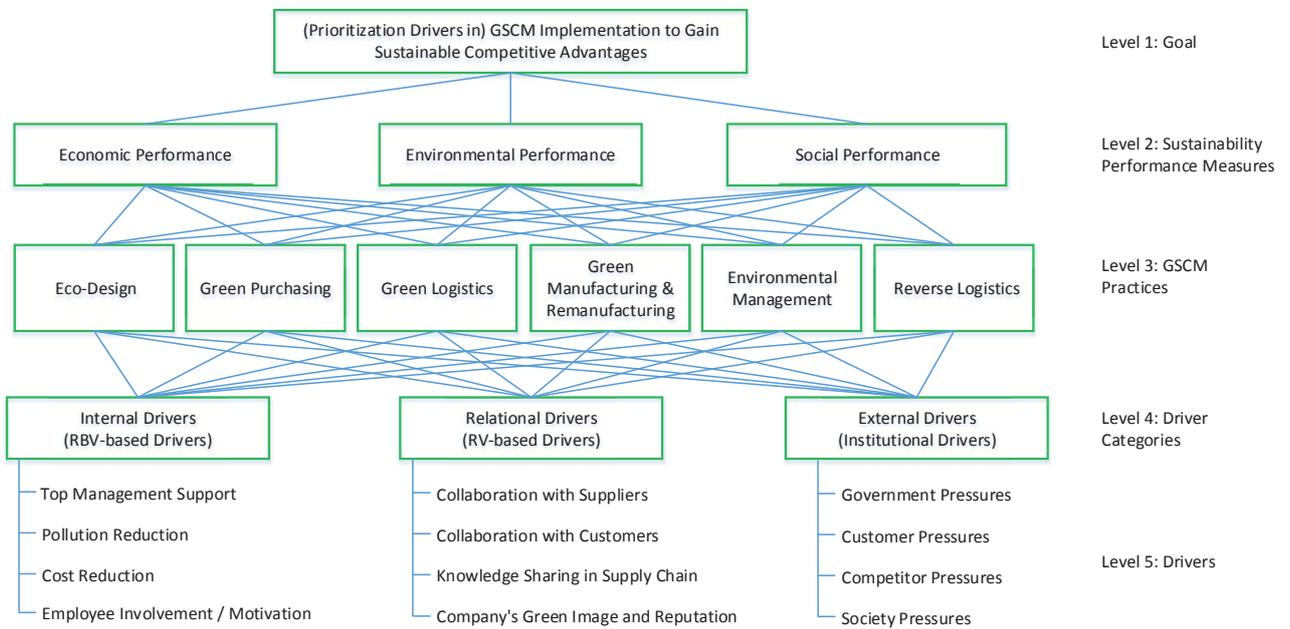
**Table 2.** Triangular fuzzy conversion scale

Linguistic scale	Triangular fuzzy scale
Equally important	(1, 1, 3)
Moderately important	(1, 3, 5)
Fairly important	(3, 5, 7)
Very strongly important	(5, 7, 9)
Absolutely important	(7, 9, 9)

Combining the opinions from several experts by using geometric mean: The perception of each expert varies according to individual experience and knowledge.

Repeating the calculation of the local priority weights for all levels in hierarchy.

Calculating the global priority weight of each element: The global priority weight of each element is calculated by multiplying its local weight with its corresponding weight along the hierarchy.



**Figure 1.** A hierarchy model of drivers to implement GSCM towards sustainability in Thai expert perspective

Accordingly, the fuzzy AHP model is developed to determine the weights of drivers in the three categories for the GSCM implementation. The global weights of GSCM drivers resulting from the fuzzy AHP calculation and their rankings by the three groups of the experts are shown in Table 3.

Taking the weight ratio of three groups of senior managers: middle managers: consultants, i.e., the weight ratio of three groups = 2:1:1 as an illustrative example. The weight ratio of three groups of senior managers: middle managers: consultants = 2:1:1 means that the weight (importance) of the senior manager group, the weight of the middle manager group, the consultant group is 50%, 25%, and 25% (or 0.50, 0.25, and 0.25), respectively; in the decision-making process, the senior manager group is considered to be two times more important than the other groups, while the middle manager group considered to be as important as the consultant group. In this study, the numbers of experts in group are 8, 10, and 9, respectively. When each expert of groups is considered to have the same weight, so,  $w_k$  which is the weights of individual of three groups are 0.0625 or 6.25% (0.50/8), 0.0250 or 2.5% (0.25/10), and 0.0278 or 2.78% (0.25/9), respectively, then  $\sum_{k=1}^m w_k = 1$ .

**Table 3.** Global weights and rankings of GSCM drivers, using opinions of the experts

GSCM Drivers	Senior managers		Middle managers		Consultants	
	Global weights	Ranking	Global weights	Ranking	Global weights	Ranking
Top Management Support	0.172	2	0.154	2	0.144	2
Pollution Reduction	0.098	4	0.100	4	0.100	5
Cost Reduction	0.094	5	0.110	3	0.101	4
Employee involvement/Motivation	0.000	12	0.043	11	0.038	11
Collaboration with Suppliers	0.035	10	0.063	8.5	0.062	6
Collaboration with Customers	0.042	9	0.035	12	0.054	9
Knowledge Sharing in Supply Chain	0.030	11	0.050	10	0.050	10
Company's Green Image and Reputation	0.051	8	0.063	8.5	0.059	7
Government Pressures	0.217	1	0.170	1	0.185	1
Customer Pressures	0.122	3	0.078	5	0.131	3
Competitor Pressures	0.059	7	0.066	7	0.056	8
Society Pressures	0.079	6	0.071	6	0.020	12

#### 4.4 Spearman rank correlation test

To see if there are any correlations between the results obtained by three groups of experts, we employ the Spearman rank correlation test. After the rankings are obtained by using the fuzzy AHP method, the correlation coefficients for pairwise comparisons of all groups of the expert panel are then examined using the Spearman rank correlation coefficient. The correlation coefficients between the rankings by three different groups are calculated. The Spearman rank correlation coefficients and p-values for pairwise comparisons of all groups of experts (senior managers, middle managers, and consultants) are given in Table 4.

**Table 4.** Spearman rank correlation coefficients and p-values

Comparison	Spearman rank correlation coefficient ( $r_s$ )	p-Value
Senior managers vs. Middle managers	0.925*	<0.001
Senior managers vs. Consultants	0.797*	0.002
Middle managers vs. Consultants	0.788*	0.002

\*Correlation is significant at the 0.01 level (2-tailed)

It is found (as noted in Table 4) that the Spearman rank correlation coefficient between the senior managers and middle managers are highly significant ( $r_s = 0.925$ ), and is higher than those of other pairs ( $r_s = 0.798$  for the senior managers vs. consultants and  $r_s =$

0.788 for the middle managers vs. consultants). Large values of these statistics result in the rejection of the null hypothesis;  $H_0$  : there is no correlation between the two groups on the rankings, at the 0.01 level of significance. Since all three null hypotheses are rejected (with p-values <0.01), it can be concluded that there is significant correlation between groups of senior managers, middle managers, and consultants on the rankings of GSCM drivers. Moreover, it can be said that there is a convergence of their opinions on the ranking as well.

## 5. DISCUSSION

The hierarchy model of drivers to implement GSCM towards sustainability in Thai expert perspective is developed through a double-screening method; Viewing GSCM drivers of sustainable development through the lenses of the organizational theories and then the fuzzy Delphi method. By applying fuzzy AHP method, this model can lead to explore the ranking (priority) of the applicable drivers affecting the firms' triple bottom line performance.

Applying Chang's extent analysis method on fuzzy AHP to determine the weight of these drivers allows considering the vagueness associated with evaluating relative importance of decision making process. The final ranking of drivers in the three categories are provided in Table 4 to facilitate the understanding of which drivers are actually important for all three dimensions of the triple bottom line. It can be concluded that Thai experts consider the category of institutional drivers as the most important driver category and the government pressures as the most important driver for sustainable development for GSCM implementation in Thailand electronics industry.

However, different industries might have a different viewpoint about adoption and implementation of GSCM practices (Zhu and Sarkis, 2006). Moreover, different countries may have a different view on GSCM adoption; environmental guidelines and regulating policies may also vary from country to country (Mathiyazhagan et al., 2013). Therefore, our findings based on Thai expert perspective may differ from other countries.

Furthermore, the Spearman rank correlation coefficient is used to determine the level of agreement between the rankings of any two groups among the three groups. Since all three null hypotheses ( $H_0$  : there is no correlation between the rankings of any two groups) are rejected, with p-values <0.01, it implies that all groups of experts *agree with each other on the ranking* of the drivers affecting GSCM implementation.

## 6. CONCLUSIONS

This study aims to determine and prioritize the drivers affecting GSCM implementation of the sustainable development goals in the electronics industry in Thailand. The theoretical drivers are identified based on a literature review through the lenses of the RBV, RV, and INT perspectives. The fuzzy Delphi method as a group decision making technique is then applied to screen drivers and to help identify applicable GSCM drivers for the context of the electronics industry in Thailand. These applicable drivers are prioritized using fuzzy AHP-based group decision making. After that the Spearman rank correlation is used to examine the relationship between the rankings obtained from different groups. The findings of the Spearman rank correlation analyses reflect considerable consistency, leading to strong support that the driver ranking is applicable across three groups of experts. Finally, some recommendations are drawn for further development of GSCM implementation towards sustainability targets.

For Thai expert perspective, the four most important drivers are 'government pressures', 'top management support', 'customer pressures', and 'cost reduction' respectively, while 'employee involvement/ motivation' is the least influential/significant driver. However, we suggest that firms, from time-to-time, would need to prioritize their drivers, practices and performance in each different stages of development, as well as continued monitoring of sustainability performance.

In promoting the success of implementing GSCM towards sustainability targets, the management team needs to devote their efforts and needs to carefully monitor and manage drivers that have the highest priority, e.g. 'government pressures' and 'top management support'. Determining the priority of drivers can help practitioners and policy makers allocate their resources and focus their efforts towards the most important drivers first or in the right order. Besides, the findings will hopefully assist Thai electronics industry in moving the policies in the right direction. Finally, we hope that these findings will be useful to international electronics firms seeking a share in the Thai markets.

Finally, some theoretical and managerial implications based on the findings of this study are developed. The formulated implications are as follows:

This study indicates that sustainable development for GSCM implementation is associated with a different set of drivers, in which some drivers are seen to be more important than the others. From Table 4, the government regulations are considered as the most important external driver of GSCM practices. Environmental regulations including pollution controls, and subsequent actions by firms can lead to competitive advantage (Porter 1991). Besides, a more proactive management of government regulation may lead to a sustainable competitive advantage. Thus, to create sustainable competitive advantage, this study suggests that firms should adopt a proactive management of government regulations and should view government regulations as an opportunity but not as a barrier or even a requirement, while government should also provide the appropriate, enabling, and sufficient legislations, regulations, policies and support.

Moreover, the research also contributes three main managerial implications. First, the findings of this study that contribute to the knowledge of the prioritization of GSCM drivers will lead to better strategic management in in-house and relational resources and the institutional drivers of focal firms. Second, the research findings will help other initiatives and government policy makers to acquire a

full knowledge of the scope and value of the drivers to build a suitable environment and provide incentives for the adoption of these GSCM initiatives. Third, the obtained priorities help practitioners understand the relative importance of the drivers, in which it is helpful to establish their strategic plans as they may not have sufficient resources to deal with all the drivers simultaneously.

## 7.0 FUTURE RESEARCH DIRECTIONS

Though our study addresses the prioritized drivers using evidence from Thailand, it omits international comparisons. Second, respondents' views on the fuzzy Delphi method and the pairwise comparisons are based on their knowledge or perception. Besides, the sample size indicates limited generalization of the study results, and the results should therefore be treated with caution. There are two directions in which this research might be extended. First, as mentioned above, different industries (or countries) might have a different viewpoint about the rankings of drivers; therefore a comparative study between industries (or countries) would be needed to further explore their differences. Second, the fuzzy AHP approach employs a time-dependent function to the different stages of development. Therefore, comparative questions of prioritizing GSCM drivers between developed (where GSCM have been well established) and developing (where GSCM have emerged) countries are worthy of study.

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# Corporate Social Responsibility and Green Chain Management: U.S. Subsidiaries at the Incheon Free Economic Zone

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## ABSTRACT

The purpose of this research is to understand the relationship between corporate social responsibility (CSR) and green supply chain management (GSCM) in the context of international business. Specifically, this study focuses on how CSR affects GSCM in U.S. Subsidiaries at the Incheon Free Economic Zone (IFEZ). Furthermore, we examine the moderating roles of cultural distance on the relationship between CSR and GSCM. Importantly, this study uses seminal international business theories to explain the relationship between CSR and GSCM in U.S. subsidiaries at the IFEZ.

**KEY WORDS:** Corporate Social Responsibility, Green Supply Chain Management, Cultural Differences

## INTRODUCTION

This paper argues that offshore manufacturing creates borderless opportunities for multinational enterprises (MNEs) to grow and achieve profitability. We chose Incheon Free Economic Zone (IFEZ) to examine important relationships related to CSR and GSCM. In particular, this study chose South Korea (e.g., Incheon) as a location context for conducting research into the phenomenon of MNE's CSR and GSCM. Specifically, IFEZ, designated at the city of Incheon in August 2003, was established in order to promote international trade and other means of foreign direct investment (FDI) (Ministry of Finance and Economy). As the first established Free Economic Zone (FEZ) in South Korea, IFEZ offered various advantages for foreign-invested firms, including tax breaks, financial support, deregulation, employment and labor management, educational improvements, foreign hospitals and pharmacies, foreign broadcasting, and administrative support (Ministry of Finance and Economy). These advantages motivated U.S. firms to develop FDI in FEZ. Relatedly, FDI is one of the most dynamic phenomena of globalization and offshore manufacturing is one of form of FDI (e.g., Ledyeva et al., 2015). This paper attempts to explain the impact of cultural distance between the U.S. subsidiaries and host country, South Korea, in order for companies in IFEZ to implement more innovative management methods. Importantly, we argue that MNE's CSR plays an important role in offshore manufacturing. GSCM has gained increasing attention within both academic research and industry (e.g., Srivastava, 2007; Hervani et al., 2005). The scope of GSCM ranges from reactive monitoring of the general environment management programs to more proactive practices implemented through various constructs such as reduce, re-use, rework, refurbish, reclaim, recycle, remanufacture, and reverse logistics (Srivastava, 2007). It is worth examining the relationship between CSR and GSCM in IFEZ because the importance of CSR has been emphasized in MNE and the role of GSCM in U.S. manufacturing firms in IFEZ is critical. Furthermore, we develop the theoretical model to explain the role of cultural distance in the relationship between CSR and GSCM.

## CORPORATE SOCIAL RESPONSIBILITY (CSR)

CSR is an important topic in business due to the economic, political and social factors that shape CSR activities in international markets (e.g., Baughn & McIntosh, 2007). CSR refers to "the managerial obligation to take action to protect and improve both the welfare of society and the interest of organizations" (Davis & Blomstrom, 1975, p. 6). CSR is mainly seen as a business's contribution to sustainable development defined as development that meets the needs of the present without compromising the ability of future generations to meet their own needs (e.g., Kates et al., 2005). Sustainable development focuses on how to integrate economic, environmental and social imperatives (e.g., Strategis, 2003; Dahlsrud, 2008).

Also, Anderson (2003) argues that CSR deals with extending the immediate interest from oneself to include one's fellow citizens and the society in which one is living, as well as acting with respect for future generation and nature. Marrewijk (2001) also posits that firms with a CSR strategy integrate social and environmental concerns in their business operations and in interactions with stakeholders and demonstrate performance. Similarly, CSR implies a moral obligation that corporations must go beyond a simple obedience to the law of the state (e.g., Kilcullen & Kooistra, 1999). CSR is the voluntary assumption by firms of responsibilities beyond purely economic and legal responsibilities (e.g., Piacentini et al., 2000). According to Pinney (2001), CSR is a set of management practices that ensure the company's operations have minimal negative impacts and maximum positive impacts on society. Marsden (2001) argues that CSR is about the core behavior of companies and their acceptance of the responsibility for their total impact on the societies in which they operate.

CSR has antecedents such as stakeholders' pressure, corporate culture, and top management orientation (Drumwright, 1994; Robin et al., 1997; Greening & Gray, 1994). On the other hand, consequences of CSR are economic performance, reputation, job satisfaction, productivity, consumer's loyalty, and evaluation of the company and its products (Abbott & Monsen, 1979; Arlow & Gannon, 1982; Aupperle, et al., 1985; Stanwick & Stanwick, 1998; Ullmann, 1985). Motives for engaging in CSR can be found in

institutional theory (e.g., Brammer et al., 2012). Specifically, Campbell (2007) argues that the institutional mechanisms influences whether corporations act in socially responsible ways, and many broad institutional and economic conditions determine whether CSR can occur. Relatedly, legitimacy can be a significant driving force behind corporations' decisions to pursue CSR in international business (e.g., Brammer et al., 2012). Suchman (1995) argues that legitimacy is the generalized perception or assumption that the actions of the entity are desirable, proper, or appropriate within some socially constructed system of norms, values, beliefs, and definition. Consistent with the call for the study on the relationship between CSR and GSCM, we attempt to examine the impact of CSR on GSCM in U.S. subsidiaries at the IFEZ.

## **GREEN SUPPLY CHAIN MANAGEMENT (GSCM)**

Organizations have been interested in environmental preservation and responsibility since the negative effects of industrialization were made public by the media (Carlson, 1962; Wu et al., 2012). GSCM plays an important role in green management, such as environmental practices, because supply chain management has unique characteristics. Wu et al. (2012) argue that since supply chain management is the one management function that connects the inside of an organization to the outside, be it suppliers or customers, and oftentimes represents the most visible corporate activities, various forms of sustainable supply chain management practices have been adopted as organizations strive to be green. (p. 183)

GSCM refers to the strategic, transparent, integration and achievement of an organization's social, environmental, and economic objectives in the systemic coordination of key inter-organizational business processes. These processes improve the long-term performance of the firm and its supply chain partners (Ageron et al., 2011). Ageron et al. (2011) suggests that environmental and social benefits are reduced when downstream and upstream partners do not have integrated into sustainable practices. GSCM can be defined as integrating environmental thinking into supply chain management, including product design, material sourcing and selection, manufacturing process, delivery of the final product to the consumers as well as end-of-life management of the product after its useful life is over (Srivastava, 2007). GSCM seeks to reduce the ecological burden by using proper material and technologies. For instance, remanufacturing restores worn-out products to like-new condition (Lund, 1984; Srivastava, 2007). A core element of GSCM is the idea that when organizations share responsibility for diverse aspects of environmental performance and GSCM reduces the environmental burden caused by industry (Hervani et al., 2005).

The growing emphasis on GSCM is driven by the increasing deterioration of the environment leading to diminishing raw material resources, overflowing waste sites and high levels of pollution (e.g., Srivastava, 2007). Green management covers all aspects of the supply chain, including product manufacture/remanufacture, usage, handling, logistics and waste management (Srivastava, 2007). The traditional supply chain is a whole process of manufacturing process, in which raw materials are manufactured into final products, then delivered to consumers (Beamon, 1999). Traditional supply chain management mainly focused on optimizing the procurement of raw materials from suppliers and the distribution of products to customers (Beamon, 1999). Extended supply chain management takes into consideration the total immediate and eventual environmental effects of all products and process (Beamon, 1999). Cottanach et al. (1995) believe that effective environmental management results in significant cost reductions at many levels. For example, it would look at the cost of purchasing hazardous materials as inputs, which result in environmental harm (Cottanach et al., 1995). It can lead to decrease cost by eliminating the need to store, manage, and dispose of or process waste, especially when waste disposal becomes expensive (Cottanach et al., 1995). Effective environmental management can also avoid stigmatization or market resistance to environmentally harmful products (Cottanach et al., 1995). Finally, it results in cost avoidance by decreasing public and regulatory hostility towards environmentally harmful organizations (Cottanach et al., 1995). GSCM requires an awareness of the many varying regulations and expectations in the international business environment. Wu et al. (2012) note that due to the differences in laws and regulations of different countries, firms that operate in various countries face a daunting challenge. Cahill & Kane (2011) also argue that for organizations with facilities in more than one state or country, compliance assurance can be very difficult if not impossible. Zhu & Sakis (2004) explain that GSCM ranges from green purchasing to integrated supply chains starting from supplier, to manufacturer, to customer and reverse logistics.

Large & Thomsen (2011) suggest five potential factors of GSCM performance: GSCM capabilities, the strategic level of the purchasing department, the level of environmental commitment, the degree of green supplier assessment, and the degree of green collaboration with suppliers. The adoption of environmental management practices by MNE firms indicate that companies are increasingly paying attention to their impact on the environment and adopting management practices to ameliorate or reduce their negative impact on the environment (Williamson et al., 2006; Welford et al., 2007; Sarkar, 2008; Wahba, 2008). Wahba (2008) discusses the moderating effect of financial performance on the relationship between corporate environmental responsibility and institutional investors. He concludes that environmental responsibility had a significant and positive effect on institutional ownership, although this was the case only when financial performance was high. It can be concluded that GSCM and CSR have a strong, positive relationship and that GSCM can lead to social and economical development in some regions, achieving CSR's main objective (Cruz & Pedrozo, 2009). Based on these theorizations, we thus propose:

**Proposition 1:** CSR is positively related to GSCM in U.S. subsidiaries at the IFEZ

## THE ROLE OF CULTURAL DIFFERENCE IN MNEs

Cultural distance is a frequently used construct in international business and it affects multiple areas of business. Cultural distance has been dealt in such areas as FDI, headquarter-subsidiary relation, and expatriate selection and adjustment (Shenkar, 2001). Shenkar (2001) asserts that cultural distance predicts choice of mode of entry into foreign markets. The cultural distance can be defined as the distance between cultural values of two different countries (Sousa & Bradley, 2006). Cultural distance also refers to socio-cultural perception of international firms between home and host country in terms of business practices, language, legal and political systems, and marketing infrastructure (Lee 2008; Holzmuller & Kasper, 1990; Johanson & Vahlne, 1977; Klein & Roth, 1990). Cho & Padmanabhan (2005, p. 309) propose that cultural distance is “the sum of factors creating, on the other hand, a need for knowledge, and on the other hand, barriers to knowledge flow and hence also for other flows between the home and the target countries”. Previous studies on both cultural distance and psychic distance have been linked to important constructs, such as ‘the degree of adaptation of the international marketing strategy, ‘the sequence of foreign investment’, ‘entry mode’, ‘control over export channels, and ‘firm performance’ (Sousa & Bradley, 2006; Leonidou & Katsikeas, 1996; Benito & Gripsrud, 1992; Agarwal, 1994; Bello & Gilliland, 1997; Evans & Mavondo, 2002). Klein & Roth (1990) suggest that the perceived difference or gap between the home country and the host country is referred to as ‘psychic distance’ or ‘cultural distance’.

On the other hand, Sousa & Bradley (2006) argue that conceptually cultural distance is different from psychic distance and that measurement methods for both concepts must necessarily be different. Tihanyi et al. (2005) argue that cultural distance is the differences between MNE’s home country and its target countries of operation. Tihanyi et al. (2005) posit that cultural distance between different countries affects MNE strategies and managerial decision-making process. Furthermore, Colakoglu & Caligiuri (2008) argue that cultural distance can be greater in a subsidiary where the culture distance between the home and the host country is greater. Gong (2003) posits that cultural distance can affect MNE performance in many aspects. Gong (2003) argues that greater cultural distance can lead to greater information asymmetry and decrease knowledge of the subsidiary’s environment, actions, and performance. Gong (2003, p. 729) illustrates that “... as cultural distance increases, complete and accurate information about subsidiary actions and performance becomes more difficult and expensive to obtain, and subsidiary activities thus become harder to interpret, making behavioral and outcome controls by the headquarters difficult”. Cultural distance plays an important role in MNE’s subsidiaries and this paper argues that similar or dissimilar cultural elements moderate the relationship between CSR and GSCM at the IFEZ.

## HOFSTEDE’S CULTURAL DIMENSIONS

Hofstede (1983) argues that nationality is important, because it is political, sociological, and psychological. Hofstede (1984) conducted surveys and analyzed its data on work-related values obtained from IBM employees working in 40 different countries. Hofstede (1991) developed cultures of nations differing by five dimensions. The first dimension is power distance. In a society with a high power distance, it is a norm that members accept and expect that the power in organizations is distributed unequally (Hofstede, 1985). The second dimension is uncertainty avoidance. In a society with high on uncertainty avoidance, members are uncomfortable with uncertainty and ambiguity, motivating them to support beliefs promising certainty and to sustain institutions guarding conformity (Hofstede, 1985). The third dimension is individualism. Members of individualistic society prefer a loosely knit social framework in society, where individuals are expected to take care of themselves and their immediate family. Opposed to individualistic society, a collective society stands for a tightly knit social framework, where individuals are expected to take care of and be loyal to not only their immediate family, but also their relatives, clan, or other in-group (Hofstede, 1987). The fourth dimension is masculinity. A masculine society is highly motivated with achievement, heroism, assertiveness, and material success. In contrast, a feminine society prefers relationships with others, modesty, caring for weak, and the quality of life. Even the women of masculine society prefer assertiveness, when the men in feminine society prefer modesty (Hofstede, 1987). The fifth dimension is long term orientation. A society is labeled as long term oriented, when a society focuses its values towards future, like thrift or persistent (Hofstede, 1993). In contrast, a society is labeled as short term oriented, when the society focuses its values towards past and present (Hofstede, 1993). The fifth dimension is about how a society sustains its roots of past, while dealing with current and future challenges (Hofstede, 1993).

Hofstede’s analysis proposes that countries that rank high on individualism rank relatively low on power distance dimension (Bang et al., 2004). On the other hand, countries with high uncertainty avoidance have controls and rules to reduce uncertainty because people tend to have a low tolerance for ambiguity and uncertainty (Bang et al., 2004). In addition, countries with high score on long-term orientation have a deep understanding and respect for their tradition and long-term commitment (Bang et al., 2004). Previously, scholars became critical of Hofstede’s study. Especially, Schwartz (1994) raised several concerns and arguments. He argues that Hofstede’s survey was not designed in order to identify dimensions of national culture so that cultural dimensions are not exhaustive (Drogendijk & Slangen, 2006; Schwartz, 1994). He also posits that Hofstede came up with cultural dimensions from data obtained between 1967 and 1973 (Schwartz, 1994). Hence, there should be major changes in culture worldwide (Drogendijk & Slangen, 2006). This research adopts Hofstede’s cultural dimensions to explain impact of cultural distance on CSR and GSCM at the IFEZ.

Korean culture generally is regarded as collectivist (Cho & Yoon, 2001). This society is likely to have strong in-group ties (Hofstede, 1991; Cho & Yoon, 2001). In contrast, the U.S. culture is very individualistic society, which means people tend to look after themselves and their immediate family (Hofstede, 2001; Hofstede et al., 2010). In the U.S. society, ties among individuals are relatively loose, personal freedom is respected, and individual decision is encouraged (Hofstede, 1980; Singh & Bartikowski, 2009). Based on these theorizations, we propose:

**Proposition 2:** Individualism (IDV) of U.S. culture negatively moderates the relationship between CSR and GSCM in U.S. subsidiaries at the IFEZ.

Korean cultures' power distance score is relatively high and it indicates that South Korea is a heretical society. Korean culture tends to value authoritarian attitudes, obedience, social hierarchies, and respect for the elderly or people with authority, coming from two different roots: Confucianism and military (Cho & Yoon, 2001). On the other hand, the U.S. society is relatively low on power distance, and it indicates that people in the U.S. society focus on equal rights in every aspect of its society and government (Hofstede, 2001; Hofstede et al., 2010). Based on these theorizations, we thus propose:

**Proposition 3:** Power distance (PDI) of the U.S. culture negatively moderates the relationship between CSR and GSCM in U.S. subsidiaries at the IFEZ.

Hofstede (1991) has graded South Korea relatively low in masculinity dimension, and it shows that Korean society is a feminine society. A low score in this dimension indicates that Korean society's dominant values are caring for others and quality of life (Hofstede, 2001; Hofstede et al., 2010). Contrastingly, the U.S. society's masculinity dimension score is relatively high. High score on this dimension explains that Americans tend to pursue their successes and achievement in their lives, rather than relationships with others or quality of life (Hofstede, 2001; Hofstede et al., 2010). Thus, this study proposes that:

**Proposition 4:** Masculinity (MAS) of the U.S. culture negatively moderates the relationship between CSR and GSCM in U.S. subsidiaries at the IFEZ.

Korean culture's uncertainty avoidance score is high and it indicates that its society has high avoidance of uncertainty. High avoidance uncertainty is more common among countries that experienced a rapid political change, such as new democracies (McCarty & Hattwick, 1992). Societies with high score on uncertainty avoidance are emotionally dependent on rules. Also, members of these societies work hard as they believe time is money and securing future is a great motivation (Hofstede, 2010). In contrast, the U.S. tends to have a greater tolerance for uncertainty (Hofstede, 1984). Based on these theorizations, we propose that:

**Proposition 5:** Uncertainty avoidance (UAI) of the U.S. culture avoidance negatively moderates the relationship between CSR and GSCM in U.S. subsidiaries at the IFEZ.

South Korea scored 100 in this dimension, meaning South Korea is one of the most pragmatic and long term oriented countries in the world. A long term oriented society seeks out for a goal that prepares for the future (Hofstede, 1993). Virtues and practical good guide Korean people in daily lives (Cho & Yoon, 2001). In South Korean corporate, employees seek out durability of companies by working for higher capital rate and growth of market share rather than quarterly profit (Hofstede, 2001). In contrast, the U.S. scored low on long term orientation, meaning that they focus on current challenges, such as a quarterly profit (Hofstede, 1993). Based on these theorizations, we propose that:

**Proposition 6:** Short term oriented culture of the U.S. culture negatively moderates the relationship between CSR and GSCM in the U.S. subsidiaries at the IFEZ.

## DISCUSSION & CONCLUSION

The purpose of this paper is to explore CSR's impact on GSCM and moderating roles of cultural distance on the relationship between CSR and GSCM in the context of the U.S. subsidiaries at the IFEZ. This study proposes that CSR is positively related to GSCM in U.S. subsidiaries at IFEZ. Due to a growing attention of environment and corporate's responsibilities of protecting them, the U.S. subsidiaries at the IFEZ will be operating their manufacturing facilities within GSCM. However, drawing from institutional theory and organizational culture behavior theory, this paper explains that five national culture dimensions from Hofstede's theory (1985, 1993) can have a negative moderating effect on CSR and GSCM. Relatively, each of five national culture dimensions of Korean society is opposed to U.S. national culture dimensions, indicating that Korean culture is greatly different than the U.S. culture. These cultural differences will be reflected into organizational culture behavior within the U.S. subsidiaries, who mostly joint ventured with South Korean partners and employed Korean employees. Due to this difference, the relationship between CSR and GSCM in the U.S. subsidiaries at the IFEZ would be negatively moderated. This paper will be beneficial for the U.S. subsidiaries with manufacturing facilities at the IFEZ.

# Green Supply Chain Collaboration: A Systematic Literature Review and Citation Network Analysis

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## ABSTRACT

A dramatically increasing competition in global market has brought a new way of operating business called “supply chain management (SCM)”. However, facing the pressure from environmental policies and regulations, each supply chain has tended to pay attention to waste generated by manufacturing processes (Klassen and Vachon, 2003). Green supply chain management (GSCM) as the process of incorporating environmental concerns into business activities was then introduced (Gilbert, 2001). This current paper aims to identify a current trend and knowledge gap, and also to find direction for new research agenda in order to fulfill the knowledge of GSCC. This paper adapted the methodology from Gopal and Thakkar (2012) where keywords searches are employed to identify articles published between 2000 and 2016 in five databases. A citation network analysis is based on the three domains of supply chain collaboration index namely; Information Sharing, Decision synchronization, and Incentive Alignment (Simatupang and Sridharan, 2005). From content analysis, the result indicates that information sharing is the most studied domain with 33 articles published (57%) followed by decision synchronization with 18 articles published (31%); whereas incentive alignment is the least popular domain with 15 articles published (26%). The analysis can also provide a direction for the future research in the area of GSCC, for example, what are the factors effecting incentive alignment activities within supply chain network?, and how competitors in supply chain should interact to gain share-value (horizontal collaboration)? Theory used in the study is another interesting area since research within green supply chain in the past mainly linked to resource-based view (RBV) and Transaction cost theory.

## KEYWORDS

Green supply chain collaboration, systematic literature review, citation network analysis

## INTRODUCTION

With the dynamic and highly competitive market, supply chain management (SCM) has been proved to be a strategic tool for enhancing organizational performance (Burgess, 1998). From the view of Cooper et al. (1997), SCM is an integrative philosophy to manage the total flow of a distribution channel from supplier to the ultimate user.” Therefor; organization will be able to reduce the cost of operation and thus increase its performance. According to Subramanian and Gunasekaran (2015), while the organizations are facing with high competition in the business environment, they are ,at the same time, confronting with a tough scenario to sustain their competitiveness. Adding the facts that the environmental issue has become one of the most important issues that can enhance or bring down the organization competitiveness in the global market (Singh et al., 2016), thing becomes even more challenging for organizations. Green supply chain management (GSCM) as the process of incorporating environmental concerns into business activities was then introduced (Gilbert, 2001). GSCM can be defined as green purchasing, green manufacturing (material management), green distribution (marketing) and reverse logistic (Green *et al.*, 1998).

For successful implementation of GSCM, manufacturers have to work collaboratively with their internal and external members which is the concept of Green supply chain collaboration (GSCC) (Sheu, 2014). From the research of Ramanathan et al. (2014), it shows that companies both in the UK and overseas are seeing collaboration in greener SC as a key factor in helping to achieve competitiveness and stakeholders’ satisfaction. Researches which are relevant to GSCC were generally found in the past decade, however; there is no complete systematic literature review regarding this concept (Gunasekaran et al., 2015). Therefore, this current paper aims

to identify a current trend and knowledge gap, and also to find direction for new research agenda in order to fulfill the knowledge of GSCC.

This paper will be structured into 4 sections as follow. The next section will explain the methodology used to conduct systematic literature review and citation network analysis. The following section will present the results of this current study both descriptive statistics and content analysis. After that the research directions will be suggested according to the results of SLR. Conclusion will be given at the end of this paper.

**METHODOLOGY**

*Systematic literature review (SLR)*

SLR is a LR that focusing on the term “systematic”. It is the review that explicitly follows the clear research questions, explicitly identifies the related papers, explicitly accesses the quality of selected papers and summarizes the literature into explicit information (Khan et al., 2003).

This paper adapted the methodology of SLR from Gopal and Thakkar (2012) where keywords searches are employed to identify articles published between 2000 and 2016 in; Scopus, ABI, EBSCO, Springer and Science Direct databases. Initial keyword searches are performed using the terms from three area; Supply chain, Collaboration, and Green (table 1.). The methodology of selecting articles for this current systematic literature review followed Lagorio, A., Pinto, R., and Golini, R. (2016) which divided into three steps; Key words and inclusion criteria; Reading titles and abstracts; Reading full paper (figure 1) .

*Step 1: Key words and inclusion criteria*

Keywords were combined using initial keywords from three areas in table 1. The combined keywords were created and “and” and “or” were used during the search in order to make sure that it will cover as many relevant areas as possible. The review was selected only peer-reviewed papers as to ensure that quality of papers selected (Burgess et al., 2006). The language was set only for publications in “English”. However, the starting year of publication was not set making a chance for researcher to see the actual starting point of the area of interest.

*Table 1 - Keywords*

Supply Chain	Collaboration	Green
Supply Chain Management Supply Chain, Value Chain, Supply Chain Integration (SCI), Supplier Integration, Customer Integration, Buyer-Supplier Relationships, Information Technology, Information Systems, Information and Communication Technologies	Collaboration, support, help, mutual aid Association, relationship, alliance, cooperation Contact, interface, relation, communication Integration, Incorporation, assimilation Alliance, pact, treat, agreement, coalition, aggregation Joint enterprises Connection, affiliation, link	Green, Green Supply Chain, Green Supply Chain Management, Waste Management, Eco-Efficiency, Reverse Logistics, Environment, Environmental Impacts, Emissions, Energy Efficiency, Ecology Sustainability, Sustainable, Performance

*Step 2: selection based on title and abstract*

The titles and abstract will be read and screen at the first place. The papers out of the research scope were removed from the list. For example, the papers which were past though *step 1* but contain some keywords which fall out of the area of interest were removed from the list.

*Step 3: selection based on full text*

The full papers will be read to justify whether each paper should be kept for further analysis or eliminated. The researcher thoroughly read true all the papers from *step 2* in order to make sure that they are relevant to the research area – GSCC.

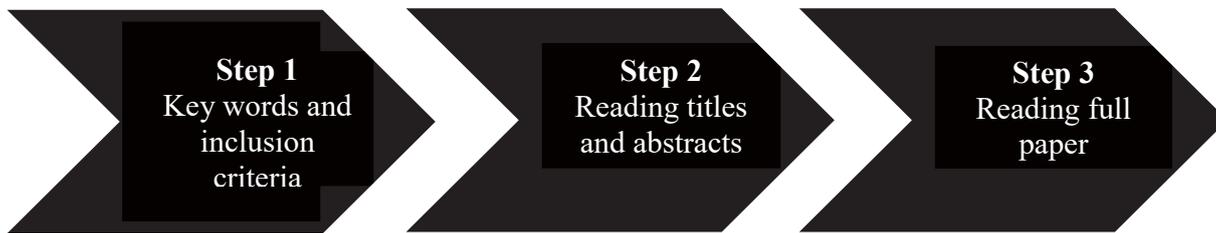


Figure 1- steps of paper selection

*Citation Network Analysis (CNA) and Main Path Analysis (MPA)*

Citation analysis is the examination of the frequency, patterns, and graphs of citations in documents. It uses the pattern of citations, links from one document to another document, to reveal properties of the documents. A typical aim would be to identify the most important documents in a collection (Wikipedia, 2016).

In this paper, CNA is conducted by using the ranking of the frequency of articles being cited within the selected papers (Sabidussi, 1966) by using Pajek software 4.01 (De Nooye et al., 2005). The domains that will be used to consider each group of knowledge in citation network analysis are as seen in table 2.

Table 2 – Collaboration Dimensions (Adapted from Simatupang and Sridharan, 2004)

Dimensions	Definition
Information sharing	The act of capturing and disseminating timely and relevant information for decision makers to plan and control supply chain operations.
Decision synchronization	A joint decision-making in planning and operational contexts. The planning context integrates decisions about long-term planning and measures such facets as selecting target markets, product assortments, customer service level, promotion, and forecasting. The operational context integrates order generation and delivery processes that can be in the forms of shipping schedules and replenishment of the products in the stores.
Incentive alignment	The degree to which chain members share costs, risks, and benefits.

Last but not least, the guideline of Main Path Analysis (MPA) (Colicchia and Strozzi, 2012) using Pajek software 4.01 (De Nooye et al., 2005) was followed in order to identifies the most relevant papers in the area of GSCC at the different time line and track how three domains have been developed.

**RESULTS**

*Summary of search*

According to the three steps of selection by Lagorio, A., Pinto, R., and Golini, R. (2016), in the first step, 1147 papers from Scopus, ABI, EBSCO, Springer and Science Direct databases were picked using the combination of three area keywords. After reading titles and abstracts in step 2, 144 papers were chosen for step 3. Finally, at the end of the reduction, there are 58 papers remained for further analysis as showed in table 2.

Table 2 - Search results

Database	No. of articles published	Number after reduction
Scopus	20	58
ABI	26	
EBSCO	50	
Science Direct	30	
Springer	18	

*Descriptive statistics by year of publication*

In order to see the trend of green supply chain collaboration issue, the descriptive statistics by journal has been assessed. From figure 2, it shows that green supply chain collaboration topic is growing dramatically from one paper published in 2000 (2%) to 11 papers published in 2013 (19%) and 9 papers published in 2015 and 2016 (16% each). It can be seen the area of GSCC is under expansion.

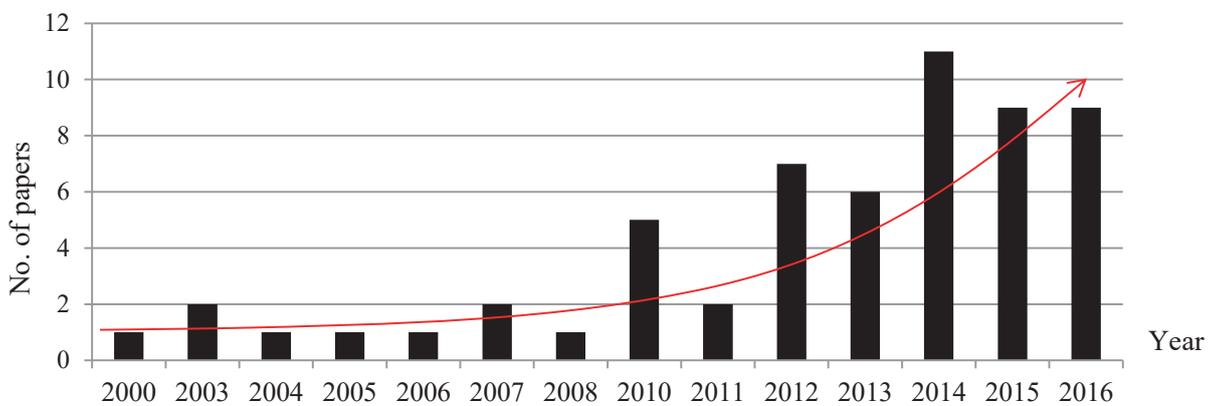


Figure 2 – Number of papers by year of publication

*Descriptive statistics by journals*

The number of papers published in each journal was calculated in order to see the influence of each journal in the field of GSCC (see table 3.). The 58 papers selected were published in 33 international academic journals, where the top three are Journal of Cleaner Production with 9 papers published during year 2003 and 2016, International Journal of Production Economics and International Journal of Production Research with 5 papers published equally during 2008 to 2016 and 2007 to 2014 respectively. Other journals with some papers published in are Transportation Research Part E: Logistics and Transportation Review with 4 papers and Sustainability (Switzerland) with 3 papers.

Table 3 – Number of papers by journals

Journal Names	Number of papers	Percentage	Time line
Journal of Cleaner Production	9	16%	2003 - 2016
International Journal of Production Economics	5	9%	2008 - 2016
International Journal of Production Research	5	9%	2007 - 2014
Transportation Research Part E: Logistics and Transportation Review	4	7%	2013 - 2015
Sustainability (Switzerland)	3	5%	2014 - 2016
Benchmarking: An International Journal	2	3%	2010 - 2012
International Journal of Operations & Production Management	2	3%	2006 - 2015
International Journal of Physical Distribution & Logistics Management	2	3%	2015 - 2015
Procedia CIRP	2	3%	2015 - 2016
Others	24	48%	2000 - 2016

*Descriptive statistics by industry-sectors*

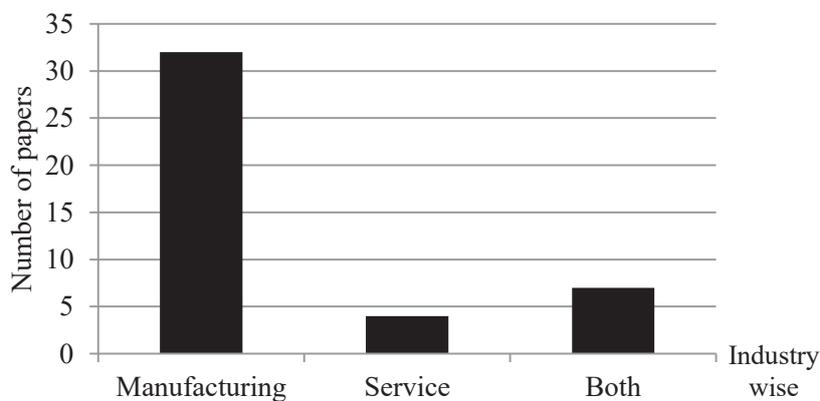


Figure 3 – Number of by industry-sectors

From 58 selected papers, there are 43 papers that identified the industries which were studied in each paper (figure 3). In this section, industry-wises can be separate into two sectors with are manufacturing and service. The majority of papers in GSCC area studied manufacturing sector with 32 papers (74.4%). There are only 4 papers studied service sector (9.3%) where 7 papers studied both sectors (16.3%).

*Descriptive statistics by methods of analysis*

There are 43 papers which were analyzed using different analysis and data collection methods (see table 4). The most popular analysis method which is “Structural Equation Modeling (SEM)” which accounted for 37 percent and collected data mainly by survey method (93.75%). The second most popular method is “Regression analysis” which accounted for 18.6 percent and data were collected through survey (100%). The third popular method is “Case study” which accounted for 11.6 percent and collected data mainly through the interviews (60%). There

are also other methods such as Qualitative analysis (Liu S., Kasturiratne D., and Moizer J. 2012), Scenario analysis (Xing, K., Qian, W., and Zaman, A. U. 2016), and Benchmarking - System Dynamics simulation analysis (Yan, M. R., Chien, K. M., and Yang, T. N. 2016).

Table 4 – Number of papers by methods of analysis

Data analysis method	Data Collection Method	Number of papers
Case Study (5)	Interview	3
	Site Visits	1
	Survey	1
Regression Analysis (8)	Survey	8
Qualitative Method (2)	Interview	2
SEM (16)	Survey	15
	Secondary Data	1
Others (12)	Others	12

*Descriptive statistics by article types*

The types of articles in this current study were classified into four types; Conceptual, Empirical, Analytical, and Applied research (Singh 2016) see figure 4. A majority of published papers fall into empirical research (44.8%) where a number of studies focus on finding factors affecting GSCC (Vachon and Klassen 2006, Lee 2010, Ateş et al. 2012, and Wu 2013). Some of the empirical research study factors that impact GSCC performance (Kim, and Rhee 2012, and Yang et al. 2013). A conceptual research is the second most studied type in GSCC (29.3%) where some of the research addressing the problems and pressures for GSCC (Ofori 2000, and Bai et al. 2010). The third top article type is analytical research (13.8%) which refers to an extensive use of operations research techniques and analytical models. The examples of studies fall into this type involve using fuzzy DEMATEL (Lin 2013), a game theoretic approach (Ghosh and Shah 2015), and a stochastic multi-objective multi-period multi-product programming model (Ameknassi et al. 2016). The least studied type is applied research (12.1%) which can be found, for example, in An integrated sustainability analysis approach to support strategic decision making in green supply chain management (Liu et al. 2014), and Development of a cloud-based platform for footprint assessment in green supply chain management (Xing et al. 2016).

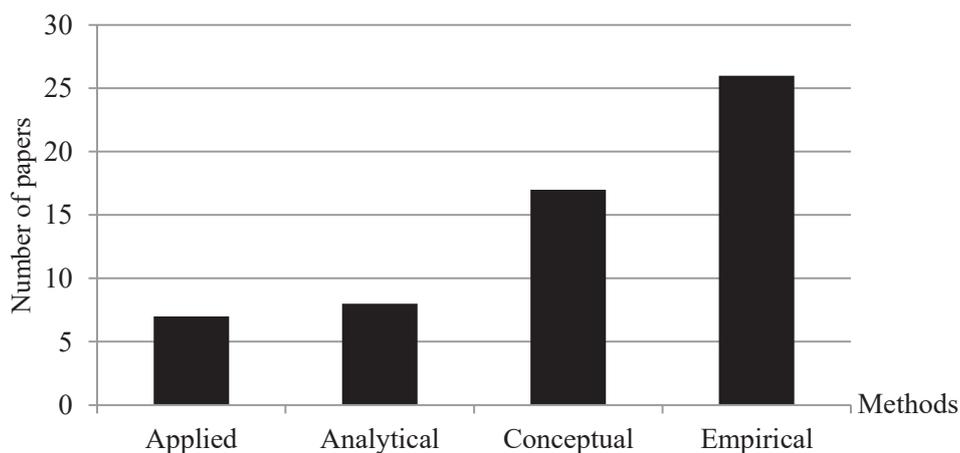


Figure 4 – Number of papers by article types

### *Content Analysis by Theories applied*

All remained 58 papers were read thoroughly in order to do the content analysis. By considering the background theory (see figure 5), it can conclude that Resource-based view theory (RBV) is the major theory being applied (5 papers) follow by Transaction Cost theory (4 papers), and Stakeholder theory (2 papers). There are also other theories which were applied in the studies such as Social capital theory, Relational View theory, Organizational Theory, and Theory of Attractive Quality (1 paper each). There is a room for other theories to be applied in GSCC research.

### *Content Analysis by types of collaboration (horizontal vs. vertical)/ scope of collaboration (external vs. internal)/ Collaboration Investigation*

Collaboration can be divided into 2 types; horizontal collaboration, and vertical collaboration. Horizontal collaboration can be defined as collaboration with competitors, internal function, and other organization whereas vertical collaboration is collaboration with suppliers, internal function and customers (Barratt 2004). A majority of the papers are related to vertical collaboration (93%), and the rest equally divided into horizontal collaboration (3.5%) and both (3.5%) as seen in table 5.

According to the scope of collaboration, there can be divided in External and Internal collaboration which involves collaborative activities within the organization or between functions; and between organizations such as suppliers, customers, and competitors respectively. For the scope of collaboration (table 5.), a majority of the papers fall into “*external*” collaboration (79%), followed by “*both*” types of collaboration (12%) and the least studied is “*internal*” collaboration (9%).

Also from table 5, the observation for Collaboration Investigation is that attention has been diversified from a strong focus on customers and suppliers, so that the investigation of “*competitors*” and “*other organizations*” can be seen in the literature of GSCC (Blanquart and Carbone 2014, and Dai et al. 2015). This fact aligns with the previous observation on types of collaboration since “horizontal” collaboration just started to be seen in year 2014.

### *Content Analysis by Collaboration domains*

From content analysis of domains (figure 6.), the result indicates that “*information sharing*” is the most studied domain with 33 articles published (49%) followed by “*decision synchronization*” with 18 articles published (26%); whereas “*incentive alignment*” is the least popular domain with 15 articles published (22%). There are 2 papers (3%) that cannot be classified into the three domains thus it falls into “others” domain.

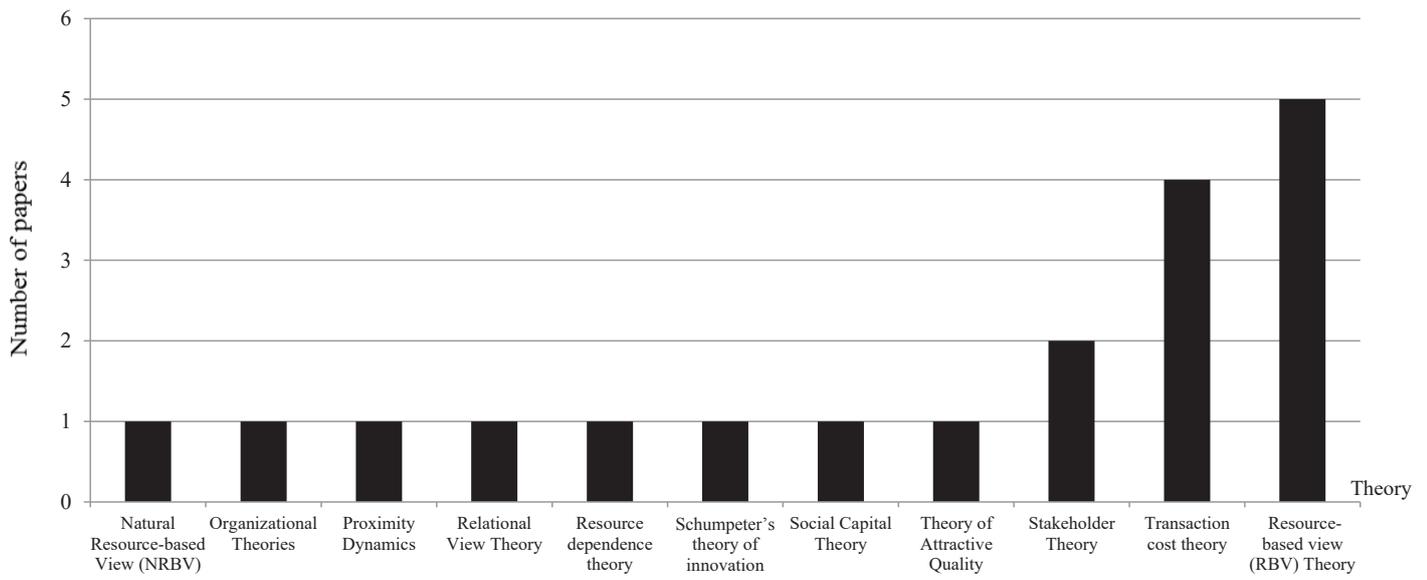
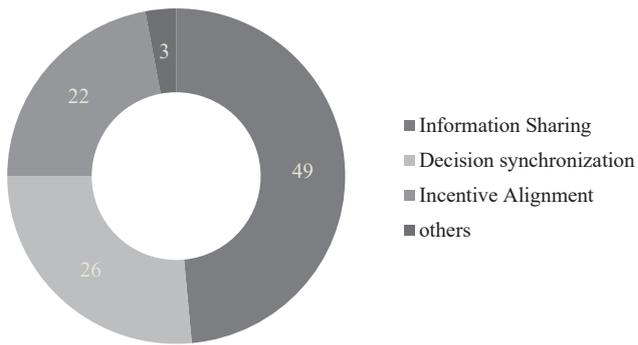


Figure 5 – Number of papers by theory applied



*Figure 6 – Number of papers by Collaboration domains*

Table 5 – Scope of Collaboration/Type of Collaboration/Collaboration Investigation

Year	Authors	Scope of Collaboration		Type of Collaboration		Customers	Suppliers	Competitors	Others
		Internal	External	Vertical	Horizontal				
2000	Ofori, G. (2000)		√	√			√		
2003	Klassen, R. D., and Vachon, S. (2003)		√	√		√	√		
	Sarkis, J. (2003)		√	√		√	√		
2004	Türkay, M., Oruç, C., Fujita, K., and Asakura, T. (2004)		√	√			√		
2005	Mintcheva, V. (2005)		√	√		√	√		
2006	Vachon S., and Klassen R.D. (2006)		√	√		√	√		
2007	Vachon S., and Klassen R.D. (2007)		√	√		√	√		
	Vachon, S. (2007)		√	√		√	√		
2008	Vachon S., and Klassen R.D. (2008)		√	√		√	√		
2010	Bai, C., Sarkis, J., and Wei, X. (2010)		√	√			√		
	Lee, C. W. (2010)		√	√			√		
	Matus, K. J. (2010)		√	√		√	√		
2010	Shaw, S., Grant, D. B., and Mangan, J. (2010)		√	√		√			
	Taghaboni-Dutta, F., Trappey, A. J., and Trappey, C. V. (2010)		√	√		√	√		
2011	Lee, K. H., and Kim, J. W. (2011)		√	√			√		
	Soylu, K., and Dumville, J. C. (2011)	√		√					
2012	Ateş, M. A., Bloemhof, J., van Raaij, E. M., and Wynstra, F. (2012)	√	√	√			√		
	De Giovanni, P., and Vinzi, V. E. (2012)	√	√	√		√	√		
	Kim, J., and Rhee, J. (2012)		√	√			√		
2012	Koh, S. C. L., Gunasekaran, A., and Tseng, C. S. (2012)		√	√		√	√		
	Liu S., Kasturiratne D., and Moizer J. (2012)		√	√		√	√		
	Ryu, J. H., Han, J. H., and Lee, I. B. (2012)		√	√		√	√		
	Youn, S., Yang, M. G., and Jungbae Roh, J. (2012)		√	√		√	√		

Table 5 – Scope of Collaboration/Type of Collaboration/Collaboration Investigation (Continued)

Year	Authors	Scope of Collaboration		Type of Collaboration		Customers	Suppliers	Competitors	Others
		Internal	External	Vertical	Horizontal				
2013	Cao, J. and Zhang, X. (2013)		√	√			√		
	de Sousa Jabbour, A. B. L., Arantes, A. F., and Jabbour, C. J. C. (2013)		√	√		√	√		
	Lin, R. J. (2013)		√	√		√	√		
	Maleki, M., and Cruz-Machado, V. (2013)	√		√					
	Wu, G. C. (2013)	√	√	√		√	√		
	Yang, C. S., Lu, C. S., Haider, J. J., and Marlow, P. B. (2013)	√	√	√		√	√		
2014	Blanquart, C., and Carbone, V. (2014)		√	√	√	√	√	√	√
	De Giovanni, P. (2014)		√	√		√			
	de Sousa Jabbour, A. B. L., Jabbour, C. J. C., Latan, H., Teixeira, A. A., and de Oliveira, J. H. C. (2014)		√	√		√	√		
	Hung, S. W., Chen, P. C., and Chung, C. F. (2014)		√	√		√	√		
	Kuo, T. C., Hsu, C. W., Huang, S. H., and Gong, D. C. (2014)		√	√		√	√		
	Liu, S., Wang, Z., and Liu, L. (2014)		√	√		√	√		
	Luo, J., Chong, A. Y. L., Ngai, E. W., and Liu, M. J. (2014)		√	√		√			
	Mitra, S., and Datta, P. P. (2014)		√	√			√		
	Ramanathan, U., Bentley, Y., and Pang, G. (2014)		√	√		√	√		
	Sheu, J. B. (2014)		√	√		√	√		
Triki, C. (2014)		√		√				√	

Table 5 – Scope of Collaboration/Type of Collaboration/Collaboration Investigation (Continued)

Year	Authors	Scope of Collaboration		Type of Collaboration		Customers	Suppliers	Competitors	Others
		Internal	External	Vertical	Horizontal				
	Chen, Y. J., Wu, Y. J., and Wu, T. (2015)		√	√		√	√		
	Chin, T. A., Tat, H. H., and Sulaiman, Z. (2015)		√	√		√	√		
	Dai, J., Cantor, D. E., and Montabon, F. L. (2015)	√	√		√			√	
	Ghosh, D., and Shah, J. (2015)		√	√		√			
2015	Gunasekaran, A., Subramanian, N., and Rahman, S. (2015)		√	√		√	√		
	Leigh, M., and Li, X. (2015)		√	√		√	√		
	Tachizawa, E. M., Gimenez, C., and Sierra, V. (2015)		√	√		√	√		
	Wong, C. Y., Wong, C. W., and Boon-itt, S. (2015)	√	√	√	√	√	√	√	√
	Yang J., Han Q., Zhou J., and Yuan C. (2015)	√		√					
	Ameknassi, L., Ait-Kadi, D., and Rezg, N. (2016)		√	√		√	√		
	Jabbour, C. J. C., and de Sousa Jabbour, A. B. L. (2016)	√		√					
	Laari, S., Töyli, J., Solakivi, T., and Ojala, L. (2016)	√	√	√		√	√		
	Li, A. Q., and Found, P. (2016)		√	√		√	√		
2016	Singh, R. K., Rastogi, S., and Aggarwal, M. (2016)	√		√					
	Susanty, A., Sari, D. P., Budiawan, W., and Kurniawan, H. (2016)		√	√		√			
	Teixeira, A. A., Jabbour, C. J. C., de Sousa Jabbour, A. B. L., Latan, H., and de Oliveira, J. H. C. (2016)	√		√					
	Xing, K., Qian, W., and Zaman, A. U. (2016)	√	√	√		√	√		
	Yan, M. R., Chien, K. M., and Yang, T. N. (2016)		√	√			√		

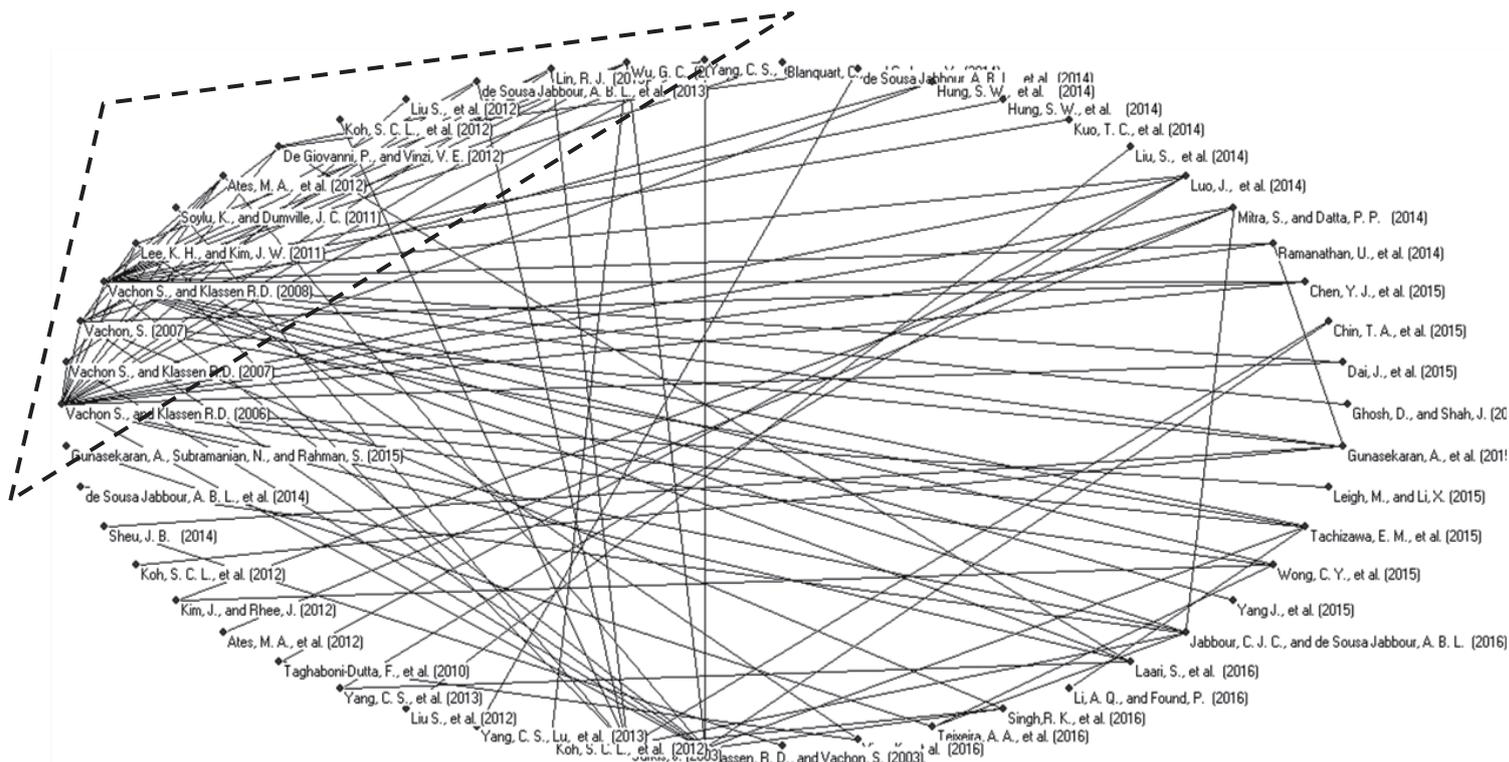


Figure 7 – Citation Network Analysis of GSCC (2000 - 2016)

### Citation Network Analysis (CNA)

A citation network analysis is based on the three domains of supply chain collaboration index namely; Information Sharing, Decision synchronization, and Incentive Alignment (Simatupang and Sridharan, 2005). A descriptive analysis of domains (Figure 6) aligns with the result of citation network analysis (CNA) created by Pajek software as seen in Figure 7. Citation network is bunched together at the left hand-side area, indicates that “information sharing” domain is a major research domain currently for GSCC.

### Main Path Analysis (MPA)

The dynamic perspective of GSCC can be achieved through the Main Path Analysis (MPA). It is designed for identifying the most relevant articles at the different time line which can create the backbone of a research in the area of GSCC. The Main Path highlights the articles that build on prior articles but continue to act as an authority in reference to later works (Lucio-Arias and Leydesdorff, 2008).

Figure 8 shows MPA of GSCC which can be noticed that the five papers at the early of the path belong to the domain “information sharing”. The next level of MPA has 2 papers which related to “decision synchronization”. While MPA of information sharing and decision synchronization domains can be conducted, incentive alignment cannot be tracked.

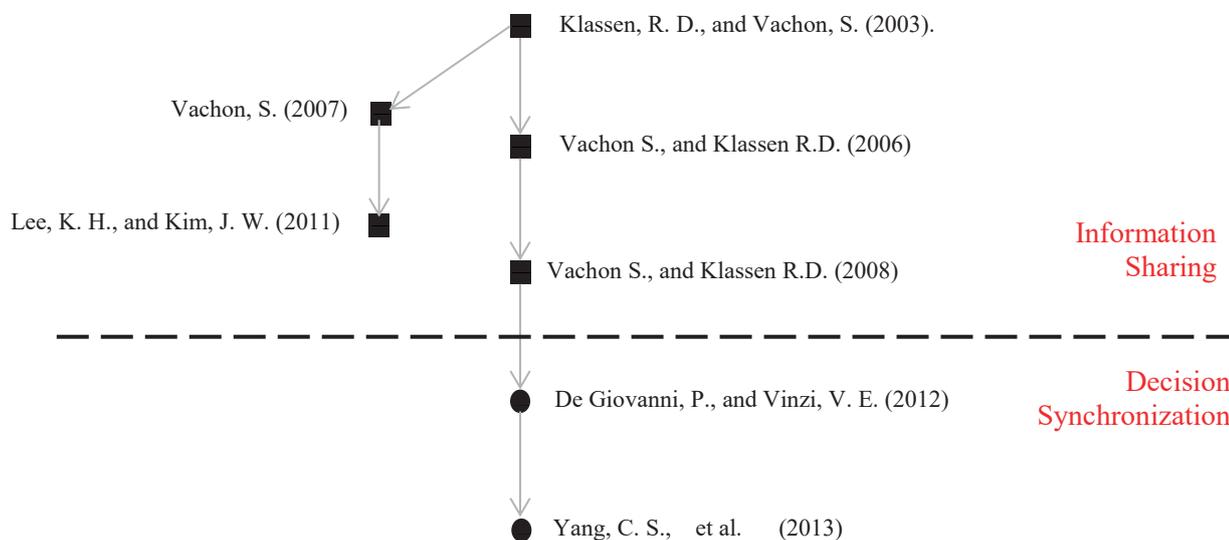


Figure 8 – Main Path Analysis of GSCC using three domains

### Research Directions

Based on the descriptive statistics, content analysis, CNA and MPA, research directions in the field of GSCC can be suggested as follow;

*Theories* – From the conclusion of theories applied, Transaction cost theory and RBV theory are the most outstanding theories during the past 16 years (2000 - 2016) in this field. “Stakeholder theory” which includes three attributes; Power, Legitimacy, and Urgency. It is one of an interesting theory which can be applied in GSCC. Although it has been used in some of the past studies that have been review, there is no study fully applied stakeholder theory (Ofori 2000 and Sarkis 2003). Green or environment issue is very critical in which to be able to understand the big picture, every stakeholder that involve in GSCC must be investigated and analyzed.

“Contingency theory” is another theory that has been applied in the field of supply chain management. The process of collaboration is complex, thus it would be helpful to apply contingency theory in the study of GSCC. (Chen et al. 2017)

*Type and Scope of collaboration* – From table 5., it can be seen that there are still lacks of studies simultaneously done in both internal and external collaboration. Therefore it is a room for research which integrated both internal (intra- organization) and external (inter-organization) collaboration. Moreover, when

consider the scope of collaboration, most of studies fall within the vertical collaboration, especially, concentrating on the collaboration with customers and suppliers. There is an opportunity for conducting research fall with the horizontal collaboration which focusing on collaboration with others partners namely competitors and non-competitors (other organizations). Especially, the collaboration with non-competitors which rarely found in the literature of GSCC. However, it would have a great contribution if both vertical and horizontal collaboration can be study simultaneously and combined all related parties.

*Domains* – From both descriptive statistics and citation network analysis, it can be found that the domains of study within GSCC field are focusing on “information sharing” and “decision synchronization”. According to MPA, only these two domains that can be tracked to see the development in the literature. The “incentive alignment” domain - The degree to which chain members share costs, risks, and benefits, should have been study more intensively to fulfill the gap in the three domains since the ultimate collaboration must be seen through all three domains.

*Methods of analysis* - From descriptive statistics – figure 4., there are rooms for “conceptual”, “analytical”, and “applied” researches in the field of GSCC. Moreover, if take a look into data analysis method (table 4.), SEM is the most popular method being adopted in this field. There are also an opportunities for researchers who can analyze data using different methods such as case study, qualitative analysis, and Scenario analysis.

*Context of analysis* – From descriptive statistics (figure 3), the previous studies in this area were conducted in the manufacturing sector. The opportunity is available for the GSCC research in service sector or even the cross-sectors.

The analysis can provide a direction for the future research in the area of GSCC, for example, what are the factors effecting incentive alignment activities within supply chain network?, and how competitors in supply chain should interact to gain share-value (horizontal collaboration)? From the research directions, researcher can see the gap and opportunities for conducting GSCC study which can contribute to the body of knowledge and also be able to applied the knowledge in the real industry, which the ultimate goal of researcher.

## Conclusion

This current study exploits citation network analysis to compliment systematic literature review (SLR). The result from content analysis was combined with the visualization of citation network analysis and Main Path Analysis (MPA) in order to draw main research area, current trend, and the direction of future research in GSCC. The current trends in GSCC were revealed in terms of descriptive statistics and content analysis. Consequently, the gaps for future research can be identified and research directions are suggested for fulfill the knowledge of GSCC.

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# Antecedents and Consequences of Climate Change Conscious Management Practices: An Entrepreneurship Interpretation

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## ABSTRACT

This study explores corporate strategies and practices in addressing climate change of South Korean firms from an entrepreneurial proactivity perspective. The cluster analysis and ANOVA with 94 South Korean companies subject to the Korea emission trading scheme present some insightful findings. First, this study identifies four different types of corporate behavior considering climate change in their business based on climate-entrepreneurial proactivity: the ‘explorer’, the ‘hesitator’, the ‘attempter’, and the ‘laggard’. Second, the ‘explorer’ cluster is likely to have a positive and proactive stance towards the Korea ETS policy. Third, climate-entrepreneurial proactivity is associated with the actual adoption and implementation of climate change conscious management practices. Fourth, the ‘explorer’ and ‘laggard’ clusters show a relatively higher operational and market performance, implying there might be a U-shaped relationship between climate proactivity and performance. Last, significant difference in environmental and emission reduction performance was not found. This study provides guidance for managers, academics and policymakers to engage the business circle in addressing climate change issues in their business.

## KEYWORDS

Climate change conscious management practices; climate-entrepreneurship; the Korea ETS; operational performance; emission reduction performance

## 1. INTRODUCTION

The past decade has witnessed that climate change emerges as one of the most critical potentials that entirely transform a competitive business environment (Howard-Grenville et al., 2014; Lash and Wellington, 2007; Kolk and Pinkse, 2005). The Paris Agreement, adopted in 2015 and entering into force in 2016, has urged firms to take a more proactive stance towards climate change. Pressure from regulations, public opinion, climate-conscious consumers and financial institutions, demanding companies to play a vital role in mitigating global warming, continues to increase (Howard-Grenville et al., 2014). South Korea, the world’s 7th biggest greenhouse gas (GHG) emitter as of 2010, announced its own voluntary medium-term mitigation goal to reduce GHG emissions by 37% the business-as-usual level by 2030. As one of the leading measures to achieve the national goal, South Korea launched an emission trading scheme (ETS) in 2015, the second nation-scale carbon market in the world. This new policy involves energy-intensive and large polluting South Korean companies across 23 sectors including power, steel, cement, petrochemicals and lumber that are collectively accounting for more than 70% of the country’s GHG emissions.

In addressing climate change issues, firms have shown different reactions. While some companies such as Exxon-Mobile, one of the major U.S. emitters, strongly opposed to unfavorable climate regulations, some others such as Pacific Gas and Electric (PG&E), Ford Motors and DuPont, took a proactive stance by lobbying for stringent climate change policies in the U.S. (Delmas et al., 2016; Jones and Levy, 2007). Prior research has attempted to gain a better understanding how firms differ in response to climate change by describing their different reactions such as ‘wait-and-see,’ ‘avoidant,’ ‘beginner,’ ‘cautious planner,’ ‘proactive,’ ‘emergent explore,’ or ‘all-round’ (Lee, 2012; Jeswani et al., 2008; Kolk and Pinkse, 2005; Levy and Kolk, 2002). However, the literature has been limited in the following ways. First, few studies have analyzed firms’ responses to climate change from a managerial interpretation perspective. Corporate environmental strategies may differ even though they are in the same competitive context (Delmas and Toffel, 2008). Managerial perceptions of environment-related risks and opportunities, organizational capabilities and the availability of slack resources within an organization influence on management decision-making, which in turn, determines the range and level of corporate response to climate change (Lee and Klassen, 2016; Banerjee, 2001). However, a topic on how firms differ in sensing potential impacts of climate change on their business, searching business opportunities from climate change, and integrating climate change issues into the strategic decision-making process, has not been explored. Second, there is little understanding of how firms’ proactive stance towards climate change, which is conceptualized as ‘climate-entrepreneurial proactivity’ in this study, influence the levels of adoption and implementation of climate change management practice across industries. Third, only a little research has examined the effects of corporate response to climate change on a firm’s actual performance including operational, market, and environmental and emission reduction performance.

In light of this research gap, this study addresses three contributions. First, we explore how firms differ in climate-entrepreneurial proactivity, characterized as sensing and interpreting climate change issues and integrating them into a managerial decision-making process. Second, this study investigates differences in corporate attitude towards the Korea ETS regulation and carbon management practices. Third, we examine how climate-entrepreneurial proactivity leads to performance regarding operations, market and emission reductions in the context of South Korea.

## 2. THEORETICAL AND PRACTICAL BACKGROUND

This section provides a brief on the South Korean government policies for climate change. South Korea once adopted the National Strategy for Green Growth in 2009 aiming to promote eco-friendly growth and contribute to international efforts to fight global warming. By this strategy, South Korea announced its national greenhouse gas (GHG) reduction goal of 30 % below business-as-usual projection by 2020. A few years later, South Korea has reset a target of cutting its greenhouse gas emissions by 37% from business-as-usual levels in 2030. In 2010, the Framework Act on Low Carbon, Green Growth was enacted, which created the legislative framework for mid- and long-term emissions reduction targets, cap-and-trade, carbon labeling, carbon information disclosure, and other related policies. The Framework Act included a system of mandatory reporting of carbon emissions by all carbon- and energy-intensive industries and provided a basis for the enforcement of a carbon trading scheme (ETS). As a precursor to the ETS, the Target Management Scheme (TMS), a greenhouse gas management program with 490 entities and 1570 sites, was introduced and officially implemented in 2010 and 2012, respectively. As of 2011, the TMS covered almost 68% of total GHG emissions in South Korea. The TMS imposed large-scale facilities emitting a substantial quantity of GHGs and consuming a high level of energy with GHG reduction and energy conservation targets obligated them to meet their goals. The legislation on the ETS, the Greenhouse Gas Emission Permit Allocation and Trade Act, was adopted in 2012. The ETS was originally scheduled to enter force in 2012, but the South Korean government delayed the start to give companies more time to prepare for this regulation.

South Korea officially launched its ETS in January 2015 amid strong resistance from the business circle and industries. The idea is to tighten regulations on companies' emissions step by step through a cap-and-trade system. The Korea ETS is split into three phases: 2015-2017, 2018-2021, and 2022-2026. In the first phase, 525 of the country's biggest emitting entities, consisting of private and government-owned organizations, have been subject to the ETS. A total 508 entities have been given a fixed amount of free emissions allowance for 100% of GHGs they are forecast to emit, based on their carbon output over the three years starting from 2012, which is called 'grandfathering allocation policy'. The other 17 firms, 4 from the petroleum, 8 from the cement and 5 from the domestic airlines industries, respectively, have been given emissions allowance, based on their relative carbon productivity to the average of each industry, which is called 'benchmark allocation policy'. Such benchmark allocation would be scheduled to extend to other industries before the second phase begins.

In phase 1, total carbon allowances will be cut by 10 million tons a year from 570 million tons to 550 million tons. In phase 2 of the program, their allocation is reduced to 97%. In phase 3, the share will be cut to 90% at most. Companies must buy allowances to offset carbon emissions in excess of the caps. Starting in 2021, they also will be able to meet some of their emissions target with foreign offset credits. Firms can earn these by making CO<sub>2</sub> emissions-reduction investments overseas.

### 2.2 Climate-entrepreneurship

Firms subject to the same set of external environmental pressure may adopt different practices and policies (Dlemas and Toffel, 2008). Managerial perceptions of external stakeholders and their demands on environmental issues have acted as a vital determinant of subsequent action (Sharma, 2000; Henrique and Sardosky, 1999). Taking proactive stance about climate change issues is one place to begin looking at how the external competitive environment is translated into corporate action. This study employs 'entrepreneurialism' to conceptualize such managerial perceptions of climate change-related environmental risks and opportunities and organizational capabilities, which are believed to influence management's decision-making (Lee and Klassen, 2016) that determines the range and level of corporate carbon strategies. In general, entrepreneurialism is understood as the activation of opportunities to combine limited resources to create value and secure returns in new ways, brought about by problem-solving practices under resource constraint and decision-making flexibility. By selectively combining concepts of entrepreneurship, environmental proactivity, and organizational capabilities, this study characterizes 'climate-entrepreneurship' consisting of three elements: sensing, seeking, and integrating climate change issues in business.

First, climate change 'sensing' is an aspect of recognizing potential impacts of climate change on business. Sensing provides the basis for being keenly aware of climate change issues and then responding to them. It does not entail careful planning by considering various alternatives. Instead, managers are involved in automatic and relatively effortless processing and learning of climate change-related information. Sensing relies on intuition, which is especially critical

in the context of surging climate change issues since it enables a firm to integrate wide-ranging stimuli into usable categories of information (Dane and Pratt, 2007). Second, climate change ‘seeking’ is a tendency to explore potential business opportunities when encountering unprecedented climate change challenges. Managers vigilantly awaiting an opportunity from climate change connect somewhat abstract outputs of climate change sensing to tangible business value propositions. They forge solutions to challenges related to climate change by using creative perspectives to develop new products, services and businesses (Sanders and Woods, 2015). Focus may be better placed on the managerial perception regarding the benefits rather than costs or risks from proactive response to climate change with respect to business performance. Firms may differ in the implementation of carbon management practices because of difference in how management assesses the consequences of their response to climate change. Management focusing on a bright side of climate change response (i.e., positive expected benefits) takes proactive stance toward climate change issues. Third, climate change ‘integrating’ is an aspect of organizational capabilities to incorporate the climate change issues into a firm’s strategic planning process. It is one of primary ways to address climate change with a high priority, which support organizational initiatives for climate change. ‘Integrating’ can offer firms an opportunity to develop valuable, potentially rare, and not easily imitable capabilities, which in turn, leads to new competitive advantage (Barney, 1991).

### 2.3 Climate change conscious management practices

In a very general sense, climate change conscious management practices include initiatives, programs, systems and procedures that firms employ to address climate change with a particular focus on greenhouse gas (GHG) emissions (Lee and Klassen, 2016; Lee, 2012). They encompass a broad range of activities in the areas of product, manufacturing process, organization, external relationship, and supply chains. This study employs a list of carbon management practices suggested by the prior research (Lee and Klassen, 2016; Lee, 2012; Weinhofer and Hoffmann, 2010; Jeswani et al., 2008; Kolk and Pinkse, 2005).

First, a low-carbon product dimension involves less carbon-intensive and more energy-efficient offerings (Weinhofer and Hoffmann, 2010). Firms develop carbon-free technologies through radical innovation as well as commercialize low-carbon technologies through incremental changes in existing products (Pinkse and Kolk, 2010). Carbon labeling such as carbon footprint can be used to boost environmental-friendly markets by informing consumers green attributes of products. Carbon footprint enables consumers to discern greener products by presenting the total amount of CO<sub>2</sub> emissions directly and indirectly embedded in a product over all the life stages (Widemann and Minx, 2007).

Second, a low-carbon process dimension focuses on increasing energy efficiency and reducing GHG emissions from manufacturing processes. It includes incremental changes in efficiency using housekeeping, refurbishment or overhauling the entire production process (Weinhofer and Hoffmann, 2010; Jesewani et al., 2008) as well as radical process innovation by adopting the state-of-the-art process technologies (Lee, 2013). Firms also opt energy source substitution of existing energy sources with cleaner or less carbon-intensive fuels, such as renewable energy sources.

Third, an employee engagement dimension emphasizes the commitment of the entire organization in addressing climate change. Firms encourage the workforce to increase their awareness and actively participate in activities on companies’ response to climate change (Jeswani et al., 2008). Firms should endeavor to integrate carbon management issues into daily business routines. Companies provide employees with environmental and climate-change-issues related training and education and incentives to pursue organizational targets for GHG emissions reduction. Such a practice frequently serves as a catalyst for driving organizational change, which in turn facilitates low-carbon product and process improvements.

Fourth, a supply chain cooperation dimension with supply chain partners, including both suppliers and customers, is crucial in addressing climate change because climate change reshapes value chains, including supply networks, production arrangements, and the provision of energy and water (Howard-Grenville et al., 2014). Supply chain partners should be engaged to reduce carbon footprints because raw material and use phases of a product’s life cycle usually account for the largest portion of GHG emissions (Lee and Cheong, 2012; Kolk and Pinkse, 2005). Firms share carbon information regarding their products and manufacturing processes with customers as well as suppliers to establish accurate carbon inventories. Collaborative research and development between supply chain partners are also required to develop low-carbon and carbon-free technologies and products.

Fifth, an external initiative participation dimension includes various engagement practices that reach external stakeholders. That encompasses participation in government-sponsored voluntary programs and policy-making process, carbon information disclosure to financial institutions, and an emission trading scheme (ETS) and carbon offset projects with other business partners (Lee and Klassen, 2016; Jeswani et al., 2008; Boiral, 2006; Kolk and Pinkse, 2005). Firms can opt such practices as a more effective way of addressing climate change. By actively taking part in an ETS, firms can achieve their carbon reduction target at a lower cost.

## 3. RESEARCH FRAMEWORK

### 3.1 Climate-entrepreneurship and corporate carbon strategies

Previous studies have attempted to classify different corporate response to climate change by characterizing the real carbon management activities that firms adopt and implement. They have proposed a wide range of models for understanding carbon activities of companies, as typology (Table 1). For example, Kolk and Pinkse (2005) highlighted this type of research by clustering FT (Financial Times) 500 firms with carbon measures and identified six distinct climate strategy configurations. Similarly, Weinhofer and Hoffmann (2010) and Sprengel and Busch (2010) examined corporate responses to climate change and derived six and four different strategies, respectively. Recently, Lee (2012) presented six various types of corporate carbon strategies in South Korea based on their varying levels of adoption and implementation of actual carbon practices.

Table 24 Varying corporate response to climate change identified in the literature

Research	Carbon strategy types	Remark
Lee (2012)	All-round explorer, emergent explorer, all-round enhancer, product enhancer, cautious reducer, wait-and-see observer	A cluster analysis of 241 Korean companies based on content analysis
Weinhofer and Hoffmann (2010)	All-rounder, compensator, substituting compensator, reducer, substituting reducer, preserver	A cluster analysis with a sample in the electricity industry
Sprengel and Busch (2010)	Minimalists, regulation shapers, pressure managers, emission avoiders	A cluster analysis with a sample of the Dow Jones global index companies
Jeswani et al. (2008)	Indifferent, beginner, emerging, active	A cluster analysis based on a continuum model with a sample from Pakistan and the UK
Kolk and Pinkse (2005)	Cautious planner, emerging planner, internal explorer, vertical explorer, horizontal explorer, emissions trader	A cluster analysis with a broad sample of FT500 companies
Levy and Kolk (2002)	Avoidant, resistant, compliant, proactive	Case studies of the petroleum industry

Source: Adopted and modified from Lee (2012)

Unlike such previous studies focusing more on actual carbon practices employed by a firm, the present study characterizes corporate responses to climate change based on climate-entrepreneurship (sensing, seeking, and integrating aspects). This approach implies corporate carbon strategies differ depending on the proactive perception of climate change and a capability how to integrate the climate change issues into a firm's strategic and managerial decision process (Figure 1). This framework distinguishes between relatively shallow and more profound approaches for each of the climate-entrepreneurship dimensions. As a result, a combination of different levels of a firm's climate-entrepreneurship indicates its particular strategy.

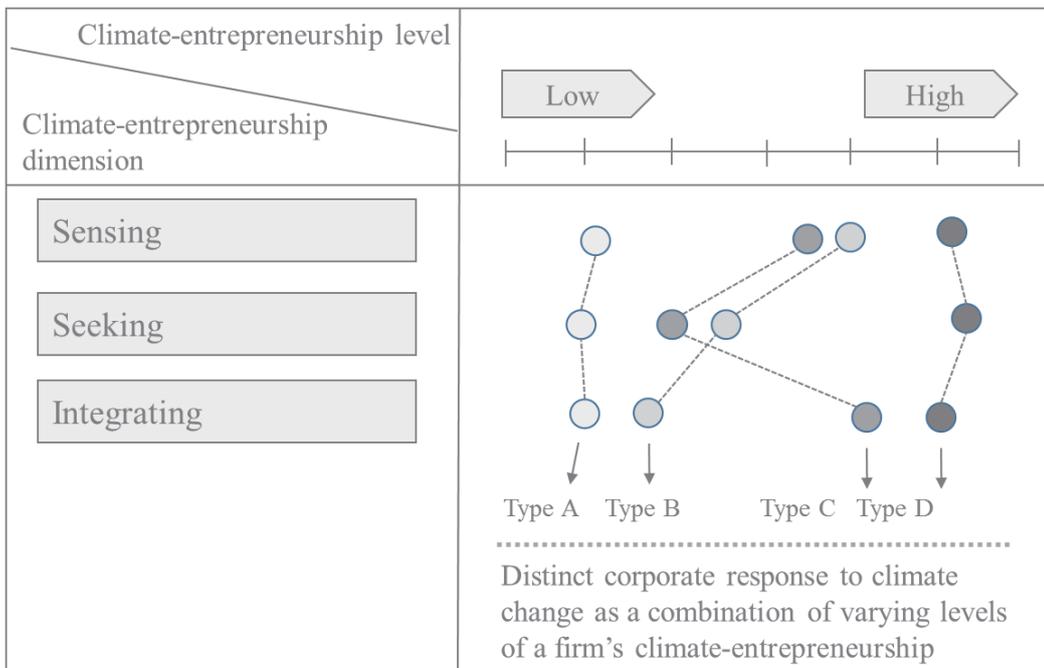


Figure 1. Climate-entrepreneurship and different corporate response to climate change

These arguments present the following proposition.

*P1. Differences in climate-entrepreneurial proactivity of South Korean firms appear as some distinct types of corporate response to climate change.*

### 3.2 Climate-entrepreneurship, carbon management practices, and performance

Previous studies have provided consistent evidence about the relationship between management's forward-looking perception on environmental issues and the adoption of new practices. A proactive response to an emerging environmental issue potentially requires significant firm-level resource investment, which is likely to be executed only when top management is determined (Klassen, 2001). Environmental championing behavior by individuals at C-executive positions influences others in the upper echelons to take pro-environment actions (Branzei et al., 2004; Anderson and Bateman, 2000). A risk-taking propensity is one of unique characteristics of entrepreneurs. Although there is a long-standing debate, an argument that risk propensity of entrepreneurs is greater than that of administrative managers has been widely supported (Stewart and Roth, 2001). For uncertain environmental issues such as climate change, managers might attempt preventive actions instead of merely responding to events that have already occurred (Aragon-Correa and Sharma, 2003). Being proactive can also help to shape the nature of future discourse with stakeholders and competitors. Management's entrepreneurial risk-taking to climate change issues that view climate change as central to competitiveness will favor a 'proactive' approach (Forlani et al., 2002).

Regulations have continued to be unpredictable, vacillating between stringent public policy favoring lower carbon emissions and little or no regulatory action in many countries. For instance, many of the firms have vigorously lobbied regulators to delay or avoid climate change related legislations by emphasizing their inability to forecast the costs and competitive impacts of such measures (Delmas et al., 2016; Jones and Levy, 2007). Thus, we expect a significant number of managers may resist or hesitate in taking precautionary actions in response to climate change and, if they have to, they may implement small token adjustments. Some others, however, that are a climate-entrepreneurial risk-taker, may have a different stance actively encouraging their organization and policymakers to creatively and proactively respond to climate change-related challenges. This reasoning leads to the following proposition.

*P2. Climate-entrepreneurial proactivity relates with the positive attitude toward climate change regulations and substantive adoption and implementation of carbon management practices. Corporate attitude towards climate change policy (the Korea ETS) and carbon management practices differ depending on climate-change entrepreneurship.*

Although there has been a long-standing argument about the relationship between environmental proactive strategy and performance, a large number of studies support a win-win possibility. A firm's proactive stance toward climate change, which is envisaged with climate-entrepreneurship and actualized with the implementation of particular carbon

management practices, can have positive effects on firm performance, including operational and market performance improvement as well as environmental and carbon emission reduction. The literature has provided evidence of and explained the positive link between a firm's climate change response and performance as follows.

First, proactive and preventive environmental management may lower manufacturing costs, avoid environmental liabilities (Karpoff et al., 2005), and enhance productivity. In production operations, carbon management practices emphasize waste reductions, efficient and effective input use, and control of internal processes, which in turn, lead to improvements in cost, quality, delivery and quick response to customer demand (Sroufe, 2003; Rothenberg et al., 2001). Second, firms may achieve revenue growth by access to new markets that climate change generates as well as by enhancing environmental reputation with greener products in existing markets (Lee, 2012; Kolk and Pinkse, 2005; Seifert et al., 2003). Tesla in the electric vehicle market and Toyota with hybrid vehicles are exemplary cases of the 'market gains,' includes market share gains, experienced based scale economies, certifications, and higher margins. Third, climate-entrepreneurial proactivity may facilitate organizational and technology learning and innovation (Lee and Klassen, 2016), which is dubbed 'innovation offsets' (Porter and van der Linder, 1995). Low-carbon and carbon-free products and processes might require a high level and multidisciplinary range of technical expertise, know-how, and technological capabilities. Such challenging efforts towards a low-carbon economy can foster organizational learning and absorptive capacity, which in turn leads to higher technological and innovation outcomes.

The primary purpose of the present paper is not to test a hypothesis about the relationship between climate-entrepreneurship and firm performance. Instead, this study examines differences in operational, market and emission reduction environmental performance between particular types of climate-entrepreneurship. This reasoning presents the following proposition.

*P3. Climate-entrepreneurial proactivity relates with operational, market, and emission reduction production.*

## 4. RESEARCH METHODS

### 4.1 The sample

The present research employed a survey method. Besides, we used actual GHG emissions and carbon productivity, evaluated as unit emission per outputs or inputs. We compiled a South Korean sample from an exclusive source, the Emission Trading Scheme Directory. In 2015, a total of 525 entities were subject to the Korea ETS regulation. We selected the general industry sector. This study targeted companies that were and would be expected to be subject to a benchmark emission allocation policy. Benchmarks are reference values for the GHG emissions, in ton-CO<sub>2</sub>, relative to a production activity, used to determine the level of free allocation that each entity within each sector would receive. In 2015, a total of 203 companies from 15 sectors were subject to the benchmark policy. A single well-informed respondent, such as managers of production, environmental or energy/utility departments, who were in charge of their firm's activities in reducing carbon emissions in products, processes, and supply chain areas as well as collaborative activities with customer, suppliers or other external stakeholders. We acquired the emissions and carbon productivity data from public sources. A total of 94 surveys were used for the analysis, representing a response rate of 46.3%. Table 2 provides a summary of the respondents.

Table 25 Demographic of respondents

Sector	Number	Benchmark*	No. of respondent	(Rate)
Building	40	26	0	0.0%
Mining	2	n.a.	excluded	
Machinery	19	2	1	50.0%
Display	5	n.a.	excluded	
Lumber	7	7	1	14.3%
Semiconductor	20	8	4	50.0%
Power	39	9	6	66.7%
Non-ferrous metal	24	n.a.	excluded	
Petrochemical	85	19	13	68.4%
Textile	15	10	5	50.0%
Water supply	3	1	excluded	
Cement	23	14	21	150.0%
Glass and ceramics	24	13	6	46.2%
Food and beverage	23	n.a.	excluded	
Automobile	26	n.a.	excluded	
Electronics	21	n.a.	excluded	
Petroleum	5	4	0	0.0%

Pulp and paper	44	39	25	64.1%
Shipbuilding	8	n.a.	excluded	
Steel	37	11	11	100.0%
Telecommunication	6	5	1	20.0%
Waster management	44	28	excluded	
Aviation	5	7	0	0.0%
Total	525	203	94	46.3%

\* No. of entities scheduled to subject to the benchmark allocation policy

## 4.2 The survey

**Three dimensions of climate-entrepreneurship.** This study identifies climate-entrepreneurship to have three dimensions: sensing, seeking and integrating. The concept is newly introduced in this study so that we developed measures based on relevant literature. We measured each of dimension with a single item. Climate-entrepreneurship ‘sensing’ is defined as “an ability of a firm to recognize and be aware of the potential impacts of climate change issues on their current and future business.” Climate-entrepreneurial ‘seeking’ is measured as “an attitude of a firm to see an opportunity from climate change challenges at being fully alert” while ‘integrating’ is depicted as “an ability of a company to incorporate climate change issues into its strategic planning and managerial decision process.”

**Climate change conscious management practices.** This study investigated the five carbon management practices, including low-carbon product, low-carbon process, employee engagement, supply chain cooperation, and external initiative participation. We measured using the Likert scale, reflecting the levels of the firm’s adoption and implementation of these practices. We employed the measurement items from some previous studies (e.g., Lee and Klassen, 2016; Lee, 2012; Jeswani et al., 2008; Kolk and Pinkse, 2005).

**Operational and market performance.** This study measured operational performance with four items based on a list of manufacturing competitive priorities that could serve primary performance goals for manufacturers, including quality, cost, delivery, and flexibility (e.g., Ward et al., 1998). This study uses increases in profits, sales and market share as a proxy for market performance. All items were perceptual measures.

**Emissions reduction performance.** This study employed two different measures for emission reduction performance. The first is a perceptual measure, consisting of three items about improvements in general environmental performance, energy efficiency, and GHG emission reduction. The second is objective measures based on actual data on emissions and production inputs or outputs, including carbon productivity (defined as ‘GHG emissions divided by unit production input or output’), changes in actual GHG emission volumes, and changes in carbon productivity. We used two kinds of carbon productivity: three-year average and the year of 2015.

**Attitude toward the Korean emission trading scheme (ETS).** This study also surveyed how firms perceive the Korea ETS regulation. Items include a company’s perception on the appropriateness of the Korea ETS enforcement and its timing, the extent of longing for postponing the Korea ETS, the readiness (preparation) to this regulation, and the extent how much difficult to cope with the Korea ETS.

## 4.3 Data analysis

This study employed a cluster analysis to categorize corporate carbon strategies from a climate-entrepreneurial perspective. First, Wardian cluster analysis with a randomly selected sample 45 observations out of the 94 respondents rendered the explanatory power and pseudo F-value supporting the four clusters were an accurate categorization. Second, the fastcluster procedure of the SAS program conducted with the 94 data presented four distinct groups. Third, the ANOVA was used to examine Propositions 2 and 3.

## 5. RESULTS AND DISCUSSION

### 5.1 Climate-entrepreneurship and corporate response to climate change

Cluster analysis presented four different types of corporate response to climate change. Table 3 shows mean scores on each dimension of climate-entrepreneurship and the number of cases in the order of the sensing, integrating and seeking dimensions.

Table 26 The result of cluster analysis

Climate-entrepreneurship dimension	Cluster 1 (Explorer)	Cluster 2 (Wait-and-see hesitator)	Cluster 3 (Cautious attempter)	Cluster 4 (Laggard)
Sensing	5.91	4.42	5.88	2.97
Integrating	5.73	4.00	5.35	2.00
Seeking	5.41	3.79	2.18	1.97
No. of cases	22 (23.4%)	24 (25.5%)	17 (18.1%)	31 (33.0%)

The first cluster shows the highest scores on all climate-entrepreneurship aspects. Companies in this group are aware of the potential impacts of climate change on their business at fully alert and likely to see an opportunity when they face new challenging competitive environment. They incorporate climate change issues into the strategic decision-making process, implying that they might have formal and systematic procedure to consider these issues in their management process. We labeled this cluster the ‘climate change explorer,’ shortly ‘explorer.’

The second group represents companies that showed a moderate level of climate-entrepreneurship. The firms in this cluster are informed about climate change issues and potential impacts on their business, and just start talking about climate change in their strategic decision-making process. In general, this cluster is recognizing and concerned with the consequence of climate change, but do not take action in a preventive way. This group is labeled the ‘wait-and-see hesitator,’ shortly the ‘hesitator.’

The third cluster has high scores on climate-entrepreneurial sensing and integrating while ranks low at the seeking dimension. This type is taking some action to cope with climate change by considering its related business issues in their strategic management process. They seem to recognize the potential business impact of climate change well; however, they are likely to perceive climate change somewhat as risks or threats rather business opportunities. We labeled this cluster the ‘cautious attempter,’ shortly the ‘attempter.’

The last cluster scores relatively low all three dimensions of climate-entrepreneurship, indicating that the companies in this group do not seriously take climate change issues into account. This type is little concerned with climate change, almost ignores it, and shows little interest in taking measures to address climate change. We labeled it the ‘climate change laggard,’ shortly, the ‘laggard.’ This cluster represents the largest number of the respondents, accounting for 33%.

Collectively, this result supports the first proposition, indicating that South Korean firms’ response to climate change differs depending on their climate-entrepreneurship.

## 5.2 Climate-entrepreneurship and attitude towards the Korea ETS regulation

The ANOVA provides very consistent results on the difference between climate-entrepreneurship about the newly enforced carbon regulation, the Korea ETS. First, Table 4 shows that the ‘explorer’ cluster is likely to have a forward-looking attitude towards the enforcement of the ETS policy. In contrast, the ‘laggard’ shows an anti-regulatory stance. The companies in this group have clear opposition to the implementation of ETS. They argue that it is the earliest days yet for the ETS in South Korea since no other countries have formally implemented the ETS on a nationwide scale, which in turn would undermine global competitiveness of South Korean firms. This stance of the ‘laggard’ is significantly different from those of the other clusters. Second, Duncan’s test presents evidence that there is a tendency the ‘laggard’ demands to put the ETS on hold or at least to delay it while the ‘explore’ apparently welcome the ETS enforcement. Third, all of the clusters show a similar and moderate level of readiness to the regulation. The ‘explorer,’ however, significantly differs from the other types to cope with the ETS, implying the companies of this cluster have less difficulty in complying with the new regulation. These results provide partial support for the second proposition, stating that climate-entrepreneurship relates with a forward-looking attitude towards the Korea ETS.

Table 27 The results of ANOVA on attitude towards the Korea ETS regulation

Attitude towards the ETS	Climate explorer (A)	Wait-and-see hesitator (B)	Cautious attempter (C)	Climate laggard (D)	Duncan’s test	F-value
a) Willingly accepting the ETS	5.0	4.2	4.5	2.7	A=C>B>D	14.65**
b) ETS timing	4.8	3.4	3.8	2.1	A>C=B>D	25.41**
c) Putting the ETS on hold	3.9	4.7	5.4	5.9	D=C>C=B>B=A	9.53**
d) Readiness to the ETS	4.1	3.1	3.1	3.9	A=D=B>D=B=C	2.60+
f) Difficulty in complying with the E	3.9	5.0	5.6	5.4	A<B=D=C	6.79**

TS					
No. of cases	22 (23.4%)	24 (25.5%)	17 (18.1%)	31 (33.0%)	

+  $p < 0.1$ , \*  $p < 0.5$ , \*\*  $p < 0.01$ .

### 5.3 Climate-entrepreneurship and carbon management practices implementation

Table 5 summarizes the results of the ANOVA, showing how South Korean firms differ in implementing carbon management practices depending on climate-entrepreneurship. First, in general, the ‘explorer’ adopts and implements carbon management at the highest level in all areas of product, process, employee, initiative participation, and supply chain, followed by the ‘cautious attempter’ and ‘hesitator.’ The ‘laggard’ ranks the lowest level. The ‘explorer’ companies are well-aware of, and better prepare for the potential impact of climate change on its business and see an opportunity at the climate change issues. They tend to much invest in developing low-carbon products and improving process efficiency as well as to more actively participate in global initiatives such as the carbon disclosure project (CDP) and to engage customers and suppliers in collaborative measures including carbon footprint. Although statistical significance was not high enough, the ‘cautious attempter’ ranks slightly higher than the ‘wait-and-see hesitator’ and ‘laggard’ clusters. The companies of the ‘attempter’ cluster better recognize and more consider the potential impact of climate change issues in their managerial decision-making process so that they implement carbon management practices at a higher level.

Second, in the employee engagement practice, the ‘explorer’ cluster shows a significantly higher level than the other groups. The companies in this cluster endeavor to integrate carbon management issues into daily business routines by encouraging their workforce to increase awareness and providing employees with climate change-related training and education. They might incorporate climate change issues into employee and organizational performance evaluation process through reward or compensation systems.

Third, noteworthy is that low-carbon process development practices are more widely implemented than the other carbon practices when addressing climate change issues. The reason behind this may be twofold. First, the companies subject to the Korea ETS regulation are energy-intensive and large GHG emitters. They have leaned toward responsive strategies of expressing serious concerns about GHG emissions, taking action to set clear reduction targets and applying such targets in their production process (Lee, 2012). For instance, firms in the steel and petrochemical industries in South Korea have prioritized the energy-saving measure to achieve GHG reduction goals for a very long time (Lee, 2013). Second, energy consumption in manufacturing processes is very closely related to production costs and profits, and thus such energy-intensive firms have focused more on process-related technology options. However, paradoxically, South Korean companies might be a lack of information and knowledge how to take action in other areas of carbon management practices such as product and supply chain dimensions.

Collectively, these results provide evidence that partly supports the second proposition, indicating that climate-entrepreneurship is associated with the actual adoption and implementation of carbon management practices.

Table 28 The results of ANOVA on carbon management practices

Carbon management practice	Climate explorer (A)	Wait-and-see hesitator (B)	Cautious attempter (C)	Climate laggard (D)	Duncan's test	F-value
Low-carbon product development	4.7	3.4	4.2	2.7	A=C>C=B>B=D	8.71**
Low-carbon process improvement	5.2	4.6	5.0	4.3	A=C=B>B=D	2.93*
Employee engagement	4.9	3.9	3.9	3.6	A>B=C=D	4.17*
Initiative participation	5.1	4.2	5.0	3.9	A=C=B>B=D	4.17**
Supply chain cooperation	4.7	3.4	3.9	2.9	A=C>C=B>B=D	7.53**
No. of cases	22 (23.4%)	24 (25.5%)	17 (18.1%)	31 (33.0%)		

+  $p < 0.1$ , \*  $p < 0.5$ , \*\*  $p < 0.01$ .

### 5.4 Climate-entrepreneurship and performance

This study examined whether differences exist between the clusters concerning operational and market performance. The results find a tendency that the ‘explorer’ and ‘laggard’ show relatively higher levels of performance than the ‘hesitator’ and ‘attempter.’ Regarding operational performance, as a composite measure of quality, delivery, cost, and flexibility, the ‘explorer’ ranks the first, and the ‘laggard’ ranks the second followed by the ‘attempter’ and the

‘hesitator.’ However, the statistical significance was not high enough. In particular, in delivery performance, the ‘explorer’ and the ‘laggard’ outperform the ‘hesitator’ and ‘attempter.’ For a customer aspect, including customer satisfaction and flexibility dimensions - an ability to quickly respond to customers’ order changes -, the ‘explorer’ shows a significantly greater level than other clusters. For market performance, a composite measure of increases in profits, revenue, and market share, the ‘explorer’ is likely to outperform slightly than other clusters; however, statistical significance is weak.

Table 29 The results of ANOVA on operational and market performance

Performance	Climate explorer (A)	Wait-and-see hesitator (B)	Cautious attempter (C)	Climate laggard (D)	Duncan’s test	F-value
Operational performance	5.7	4.7	4.8	5.3	A=D>D=C>C=B	5.60**
- Quality	5.4	4.7	4.8	5.3	-	1.62
- Delivery	5.8	5.0	4.9	5.9	D=A>B=C	5.69**
- Cost	5.0	4.2	4.7	5.0	A=D>D=C=B	4.11**
- Flexibility	5.9	4.9	4.8	5.3	A>D=B=C	5.56**
Customer satisfaction	5.6	4.9	4.8	4.9	A>B=D=C	3.57**
Market performance	5.1	4.2	4.4	4.5	A=D>D=C=B	3.22*
- Profit	5.1	4.3	4.8	4.7	A=C=D>C=D=B	1.77
- Revenue	4.8	3.8	4.0	4.4	A=D>C>D=C=B	2.31+
- Market share	4.8	3.8	3.8	4.3	A=D>D=B=C	3.24*
No. of cases	22 (23.4%)	24 (25.5%)	17 (18.1%)	31 (33.0%)		

+  $p < 0.1$ , \*  $p < 0.5$ , \*\*  $p < 0.01$ .

Noteworthy is that the ‘explorer’ and the ‘laggard,’ which are antipodes of climate-entrepreneurial proactivity, seem to show relatively higher performance than the ‘hesitator’ and ‘attempter.’ That implies that there might be a U-shaped relationship between environmental proactivity and firm performance, depicting that a negative and a positive effect of climate-entrepreneurship depends on its level. This result is in line with those of previous studies corroborating evidence that corporate environmental or social responsibility has a non-linear and U-shaped relationship with firm performance (e.g., Trumpp and Guenther, 2017; Barron and Salomon, 2013). For instance, Trumpp and Guenther(2017) suggest a theoretical framework of the ‘too-little-of-a-good-thing’ (TLGT) by integrating the trade-offs and win-win hypotheses between corporate environmental performance (CEP) and firm performance. They argue that companies can benefit from CEP only when it goes above a particular minimum level as a threshold. If we interpret the four clusters positioning on a continuum of climate-entrepreneurship, the ‘laggard’ and ‘explorer’ are at an antipode, and the ‘hesitator’ and ‘attempter’ are in between them. Then, they seem to follow the U-shaped relationship between climate-entrepreneurial proactivity and performance. This conjecture, however, should be further tested.

### 5.5 Climate-entrepreneurship and environmental and emission reduction performance

The ANOVA result (Table 7) provide weak evidence that there is a difference in emission reduction performance in an objective measure between climate-entrepreneurship. For perceptual measures, the result finds a tendency that the ‘explorer’ and ‘cautious attempter’ show higher levels than the ‘hesitator’ and ‘laggard’ in improving environmental performance and curtailing GHG emission reduction.

Table 30 The results of ANOVA on environmental and emission reduction performance

Performance	Climate explorer (A)	Wait-and-see hesitator (B)	Cautious attempter (C)	Climate laggard (D)	Duncan’s test	F-value
Perceptual measure						
- General environmental performance	4.9	4.0	4.7	4.3	1=3>3=4=4=2	5.06**
- Energy consumption reduction	4.7	4.1	4.8	4.2	-	2.47+
- GHG emission reduction	4.9	3.9	4.3	3.7	1=3>3=2=4	5.33**
Objective measure						
- Carbon productivity	0.375	0.379	0.443	0.388	-	0.21

- Change in GHG emissions	0.016	0.057	0.020	0.020	-	0.49
-Change in carbon productivity	0.022	-0.001	0.030	-0.021	-	1.10
No. of cases	22 (23.4%)	24 (25.5%)	17 (18.1%)	31 (33.0%)		

<sup>+</sup>  $p < 0.1$ , <sup>\*</sup>  $p < 0.5$ , <sup>\*\*</sup>  $p < 0.01$ .

Collectively, the results in the sections of 5.4 and 5.5 provide partial support for the third proposition. This study found differences in operational performance between climate-entrepreneurship types, while we did not confirm any significant difference in environmental and emission reduction performance. Besides, the ‘explorer’ is likely to show higher levels of operational and environmental performance in perceptual measures; however, no significant differences were found between the other clusters of the ‘cautious,’ ‘hesitator,’ and ‘laggard.’

## 6. CONCLUSION

### 6.1 Managerial implications

The Paris agreement in 2015 has concentered global consensus on fighting against climate change. Pressure and expectation from governments, public opinion, consumers and financial institutions onto firms to play a vital role in mitigating climate change impacts continue to increase. Companies have shown a different reaction in addressing climate change issues depending on how they interpret its impacts on their business. This study provides some implications for managers as well as policymakers that attempt to proactively address climate change issues in firms’ strategic and managerial decision making.

First, companies vary in sensing the potential impact of, seeking an opportunity from, and integrating climate change issues into their strategic decision-making process. Firms should recognize that climate change is not an environmental issue, but a market issue for business with climate-entrepreneurship, which ultimately transforms existing competitive business contexts. Second, policymakers often encounter stiff resistance from the business circle when they attempt to take measures for mitigating climate change. Governments need to realize that such resistance does not reflect real voices of the entire businesses because enterprises have very different attitude and understanding towards climate change. Policymakers should focus more on such firms having a more forward-looking and proactive stance and implement policies to encourage such climate-entrepreneurial companies. Third, companies need to realize climate-entrepreneurship may enhance competitiveness in emerging markets as well as existing markets without compromising profitability. It is also noteworthy that benefits of climate-entrepreneurship on operational and market performance could be secured only when such proactivity exceeds at a certain level of a threshold. Endeavoring to consider climate change issues in their business with entrepreneurial spirits, however, eventually brings firms benefits.

### 6.2 Limitation and future research

By stating some limitations, this study suggests the directions for future research. First, this study identified four distinct types of climate-entrepreneurship. This concept, however, was first introduced in this study so that it should be more elaborate based on relevant theories and with more valid and reliable measurement items. Second, the results of this study cannot be generalized as themselves because they were quite context/time-specific results. Much research is needed to understand the corporate response to climate change in different contexts (e.g., the other OECD countries and emerging economies). Furthermore, future research based on longitudinal perspectives is warranted to understand better how climate-entrepreneurship changes over time. Third, the survey was limited because this study focused on energy-intensive and large polluters subjected to the Korea ETS regulation. The relatively small sample may not reflect the real situation of the entire South Korean firms and may have led to some statistical bias as well. The future research needs to extend the sample including the service sector and small- and medium-sized enterprises to enhance the generalizability of this study’s findings. Last, objective financial measures such as ROI, Tobin-Q, and profits should be included to examine differences in firm performance in future research.

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## Appendix: Questionnaire items

Construct	Item code	Items
Climate-entrepreneurship		To which extent do you agree or disagree with each following statement ( <i>1=not at all, 4=moderately, 7=great extent</i> )? <i>Over the past three years, your company...</i>
Sensing	SEN01	has been well aware of the potential impacts of climate change issues on our current and future business
Seeking	SEE01	has been seeing a business opportunity from climate change challenges
Integrating	INT01	has been considering climate change issues in our strategic management decision-making process
Attitude towards the Korea ETS		To which extent do you agree or disagree with each following statement ( <i>1=strongly disagree, 4=moderately, 7=strongly agree</i> )?
	ETS01	Our firm willingly accept the Korea emission trading scheme (ETS) implementation
	ETS02	It is timely the Korean government implements the ETS regulation.
	ETS03	The enforcement of Korea ETS should be postponed
	ETS04	Our firm has been preparing for the Korea ETS enforcement
	ETS05	Our firm finds it difficult to comply with the Korea ETS
Carbon management practices		To which extent do you agree or disagree with each following statement ( <i>1=not at all, 4=moderately, 7=great extent</i> )? <i>Over the past three years, your company...</i>
Low-carbon product development	CMP01	has continued to develop energy-efficient or less carbon-intensive products
	CMP02	has invested in R&D for less carbon-intensive products/technologies
	CMP03	has continued to undertake projects to increase energy-efficiency in your production processes
Low-carbon process improvement	CMP04	has continued to conduct projects to reduce greenhouse gas (GHG) emissions in your production processes
	CMP05	has introduced innovative process technologies to dramatically reduce GHG emissions in your production
	CMP06	has substituted exiting energy sources with cleaner fuels
Employee engagement	CMP07*	has integrated carbon measures into your firm's performance evaluation and compensation system
	CMP08*	has engaged the entire employees and departments in reducing GHG emissions by utilizing management systems such as internal emission trading schemes
	CMP09*	has provided employees with environmental and climate-change-related education and training
External initiative participation	CMP10	has actively participated in global initiatives fighting climate change (e.g., Global Compact, UNEP/Financial Initiative)
	CMP11	has transparently disclosed your firm's GHG emissions information (e.g., the carbon disclosure project; CDP)
	CMP12	has acquired emissions permits by utilizing carbon markets (e.g., ETS, clean development mechanism (CDM))
Supply chain cooperation	CMP13	has shared carbon-related information and knowledge with major customers and suppliers
	CMP14	has undertaken collaborative work to develop less carbon-intensive products with major customers and suppliers
	CMP15	has shared carbon-related information and knowledge with major customers
Performance		For each of the items listed below, how does your firm compare with primary competitors? ( <i>1=far worse than competitors, 4=about the same as competitors, and 7=far better than competitors</i> )
Operational performance		

	OPER01	Quality
	OPER02	Cost
	OPER03	Delivery
	OPER04	Flexibility
	CUST01	Customer satisfaction
Market performance		
	MPER01	Profit increase
	MPER02	Revenue increase
	MPER03	Market share increase
Environmental performance		
	EPER01	Environmental performance
	EPER02	Energy consumption reduction
	EPER03	Greenhouse gases (GHGs) emission reduction

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# Social Robotics for Seniors: Customer-build versus Adapted from Existing “Off the Shelf” Technologies

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## ABSTRACT

This paper initially reports on a usability and acceptance trial on the use of telepresence robots. The object was to assist the elderly by encouraging virtual social interactions in an attempt to reduce social isolation and loneliness. The trial results were disappointing because the telepresence robot under study had a number of technical problems which meant that the trial had to be abandoned. This has led us to examine the whole process of building technology to suit a specific purpose (older people at home) versus adapting existing technology to fit into a specific context. To this end, the paper assesses two approaches through the use of two different telepresence robots. We hope this paper can also assist future researchers in this area to be more circumspect in their expectations of the technology. We found that one cannot simply assume that the technology would work and channel all their resources into usability and acceptance testing. It may be the case that a significant amount of effort is needed to get the technology to work in the chosen environment before any acceptance testing can be carried out.

## KEYWORDS

Robotics, Telepresence, Seniors

## INTRODUCTION

This paper reports on a research project investigating the use and usability of a telepresence device for seniors. This device encountered technical problems which lead to a team reconsideration of the best approach for developing and implementing assistive technologies for older people. The premise is that the findings reported in this paper can help future researchers with ways to ensure that user acceptance testing can be done without concerns about the reliability of the technology. In this paper we discuss the concepts of custom built technology that can be made to be “fit for purpose” through modifications based on user feedback versus “off the shelf” technologies that can be used in its present form with end-user adaptations with respect to the context of usage. The paper starts with an introduction to the rationale for initially using the custom-built solution and then goes into discussions as to the benefits of custom built versus “off the shelf”. This is followed by a description of the problems that were encountered with the custom-built robot.

Information systems has had a history of advocating the development of user friendly, relevant and timely IT artefacts for use in real world situations and this has been evident in the vast amount of research undertaken in the past with respect to technology adoption models (Davis, Bagozzi and Warshaw 1989, Fishbein and Ajzen 1991). There has also been a great deal of research that indicates that providing options for people to have an input in the technology being developed will result in better outcomes and products that will fit the needs of individuals (Eisma, Dickinson, Goodman, Syme, Tiwari and Newell, 2004). For example, evolutionary prototyping has been used in the past to help end users tailor products to their own requirements (Carter R.A., Anton A.I, Dagnino A and Williams L 2001); Xiaoshuana Z, Zetiana F, Wenguib C, Donga T, and Jianc Z 2009).

This approach of providing IT products that will be used and are effective for end user needs has often led to the development of new and innovative products designed to fit the special needs of the market. This is especially the case in markets that may differ to the main stream. An example is this project working with aged care individuals who may be less technically skilled and have no strong imperative such as job requirements to adopt the technology. The expectation was that in the aged care area, devices and software that are tailored to meet the specialised needs of the demographic would be more acceptable to end users than off the shelf devices and/or software.

In this paper we refer to the approach of providing tailored solutions for a specific market as custom built. Conversely, the other approach is using and adapting existing technologies for use in the specialised market. In this paper we will refer to this as adapting existing technologies to suit a specific purpose or market. We will be investigating these two concepts in relation to research we have been conducting into the use of Telepresence robots to help reduce social isolation and loneliness amongst older people.

## BACKGROUND

The world’s population is aging at a rapid pace, as the percentage of older adults will increase to 24% by 2030 in comparison to 10% in 2000. This phenomenon has several impacts on the economic and social dimensions of developed countries. One impact is a future shortage in the number of professional caregivers as well as financial impacts to the countries due to the aging populations (Bemelmans et al., 2012).

One of the issues that can affect older adults is that they can experience loneliness or social isolation as they lose partners and friends due to death, moving to a new location disability or other life changes. There is a risk that a person's social activity will become limited as access to family members and friends is more difficult with difficulty in mobility. Feelings of loneliness or decreased social activity has negative impacts including but not limited to cognitive functions (Cacioppo and Hawkley, 2009) (Shankar et al., 2011), bad sleeping patterns, deteriorated physical conditions and low level of energy during daytimes (Hawkley et al., 2010a), high or low blood pressure (Hawkley et al., 2010b) and mental health issues (Wilson et al., 2007).

Findlay (2003) stated some successful interventions for decreasing social isolation in seniors were teleconferencing, support groups, service provision and Internet usage. Seniors form a fast growing group of computer and Internet users (Findlay 2003) but Wagner, Hassanein and Head (2010) state that two conditions need to exist for seniors to effectively use technology. That is, a supportive environment and self-efficacy in computer use. Therefore, there needs to be interventions to equip the community to support active citizenship in seniors.

One of the high impact areas in recent years is robotic technology which appears to have significant potential to address the demographic changes associated with the aging of the population with products that can assist older adults (Pollack, 2005).

Robotic technologies used for older adult problems can be divided into nine categories; companion, telepresence, manipulator service, rehabilitation, health-monitoring, reminder, domestic, entertainment and fall detection/prevention robots. This paper will focus on telepresence robots.

Telepresence robots are robots that provide two-way communication between two persons, which may assist in aiding the maintenance of social networks in older adults. The provision of a telepresence device as distinct from a telephone offers an easy to use means of providing rich communications and has been shown as beneficial in bringing together distant grandchildren with their grandparents (Yuan et al. 2015). This may also be beneficial to people who have lower levels of hearing as they can supplement the spoken word with lip movement, facial expression and gestures to aid understanding. Some of them have in-home navigation ability to provide guidance for a remote user (Kristoffersson et al. 2011). One of the most important aspects of communication is a sense of connectedness, which helps individuals not to feel lonely. They could also have benefits for people with cognitive impairment problems and help them to stay in their homes. This monitoring approach offered by the telepresence robot implies that family members living away from the person can still play a role in their day-to-day care and allows the senior to play an active role in their extended family life. The use of these devices may allow seniors to safely stay in their own homes and the communities within which they have existing social links.

Design and developing a telepresence robot for aged care could be seen in two ways: robots that need to be customized for each elderly (or type of the elderly) person and general robots that could be used for everyone with minimum or no customization. As needs of older adult can be seen as very different from a younger demographic with the dimensions of gender, age and physical and mental conditions, some researchers have tried to address this issue by design and develop customized robots. Others have argued that by using existing off the shelf technologies, we are able to address the needs for older adults with same quality and lower expenses due to a larger market and therefore lower cost per unit of the design process. This research intends to investigate case studies of these two types of telepresence robots for aged care.

### ***Telepresence Robots***

This paper will investigate two case studies of telepresence robots for aged care on the Sunshine Coast in Queensland. The two case studies are a custom designed solution for aged care needs called the Giraff robot and a generic telepresence device called the Double robot. The Giraff robot is part of the Victoryahome project based in the European Union and was part of a general evaluation of a number of technologies to help older people stay at home (Victoryahome 2016). For this paper we were specifically looking at the performance usefulness of the telepresence robot (Giraff) component of the Vistoryahome project. The Giraff robot was developed by Giraff Technologies AB, a small to medium enterprise (SME) based in Sweden.

The Giraff robot has been evaluated in various sites in Europe (Moyle et al. 2014) and at two sites in Australia. It is the results from one of the Australian sites that will be discussed in this paper.

As will be shown later in this paper, the Giraff robot was plagued with technical problems and this led us to purchase another telepresence robot called a Double. The Double robot is designed for use in businesses and classrooms and is based upon Segway technology with an Apple iPad as the connecting device. Therefore, the Double robot was not designed for any specific use in aged care.

### ***The Giraff Robot***

The Giraff telepresence robot was developed in Europe and supports video conferencing and remote manoeuvring of the machine around the living space. The Giraff can be remotely activated by a 'secondary user' (care workers and loved ones who want to contact the primary user using the telepresence robot) to request a visit to the 'primary user' (the older person). The primary user can see an image of the caller on the Giraff screen and can either accept or reject the incoming call. Some secondary users can also be given permissions that allow them to make 'emergency' calls, where they can activate the Giraff and start a visit without any

intervention by the primary user, in order to check the well-being of the primary user. There are also extension services for fall detection and medication adherence that are associated with the Giraff, but these were not used in this study.

The Giraff robot is a large machine, which includes a full size desktop computer tower plus batteries. It has the ability to raise and lower the interaction screen, change the screen angle (like nodding the head of the Giraff), zoom the camera on a specific area, switch to night vision for dark rooms, and finely control the speed and manoeuvrability of the machine.

Evaluations of the device were in the form of a controlled research trial with the results meant to inform further development of the device in order to provide a solution that would as closely as possible fit the needs of older people living in their own homes. The trial was extensive with 43 sites across Europe and two sites in Australia. As the trial was designed to determine the usefulness of the Giraff robot, a series of questions were asked both from the primary user and the secondary users.

### ***The Double Robot***

The double robot is a lightweight device based on Segway technology, which is scaled down as it is designed to carry a 9.7" Apple iPad as the computing device. The iPad also acts to control movement and offer the interaction screen for users. The iPad is not sold with the device but is supplied by the user offering a simple upgrade path for the interaction technology. The device is designed for use as a remote-controlled mobile virtual presence device and has a wide range of use cases such as virtually attending meetings or classes. The remote caller (secondary user) has full control over the robot, can initiate visits without permission from the primary user, can drive the robot around, raise/lower the 'head', while having two-way audio and video communication.

In this case study we aim to test usability of this device for the same aged care market that the custom Giraff robot is intended for.

## **RESEARCH QUESTIONS**

Therefore, the research question for this paper is:

RQ: What are the benefits and drawbacks of a customised solution compared to an adapted off the shelf solution telepresence device for use and acceptance in aged care?

### ***The Research Project***

The Australian extension of the Victoryhome project had many problems from the beginning. For example, two features that were part of the add on benefits in using the Giraff, namely the fall detector and the medicine dispenser were unable to be used. In the case of the fall detector, it could not be activated and was unable to be used, there are also more technological advanced fall detection devices now available in the market. In the case of the medicine dispenser, we could not obtain ethics approval for such a device as it contravened the Therapeutic goods administration's Australian standards for the dispensing of medicines. The omission of these two components of the robot usage effectively meant that the Giraff robot in Australia was a telepresence device without the extra benefits associated with the European study.

The two sites in Australia were in the Sydney and Sunshine Coast regions. The Sydney participant was a 63 years old male living on the second-floor of a house, with his carers living on the ground floor of the same house. His main communication device was making calls with a smartphone and email. After using the Giraff, an interview was carried out by a family member who is in contact with the participant. The ability to navigate through the home assisted in monitoring was considered to be the most positive facet of using Giraff compared to Skype and Facetime for this family member acting as an informal caregiver. They also appreciated the ability to see when their family member had returned home from an outing.

The Sunshine Coast site participant was a 65-year-old male with limited mobility, living alone. Due to technical difficulties with the Giraff robot, no evaluation of the benefits of the device could be made because we could not get it to work reliably, as described below.

### ***Customised solution – the Giraff***

The customised solution has the potential to provide a great number of benefits for the usability and functionality within a specific area. These include the following;

1. The technology can be improved based on the problem at hand;
2. The research trial provides an effective feedback loop;
3. User involvement and ownership in the product will be much higher;
4. Care providers have an opportunity to use the technology directly.

In the following section, each of these four benefits will be expanded upon.

The technology can be improved based on the problem at hand

Customisation at this level is similar to an evolutionary prototyping approach in software development whereby end users can provide details of changes they feel can improve the robot based on their own situation. This provides a very powerful and direct tool for developers to make relevant and practical improvements quickly. This is considered a major advantage of a customised solution over an adapted solution because it should allow for a solution that more directly fits the end user's requirements.

The research trial provides an effective feedback loop

This feedback loop can be from the end-users directly to the developers and should be captured in the end-user responses to the research trial. The VictoryaHome research trial was designed to provide that feedback loop with both primary and secondary users being interviewed and filling in questionnaires related to usability.

User involvement and ownership in the product will be much higher

It is expected that people using the customised solution will have some ownership of the device. However, this could only work if the device offers functional improvements for the user. It could (and in this case did) have an opposite effect in that failures in the technology itself would have a detrimental effect on involvement and ownership.

Care providers have an opportunity to use the technology directly.

Through the VictoryaHome project, care providers should have been able to have some input into any modifications that could improve the usage by their clients. However, due to the technical problems associated with the device itself, this resulted in a great deal of frustration and a lack of confidence in the technology.

However, there are also disadvantages with the use of customised technology solutions. These include the following;

1. The resources available can be limiting;
2. The evolutionary nature of improvements can be lost;
3. The technology may not be generic;
4. Technical problems can inhibit customisation and implementation.

As in the earlier section, each of these four disadvantages will be expanded upon.

#### ***The resources available can be limiting***

The customisation approach is usually associated with a research trial as this provides the end-user feedback needed to make improvements and customise the product to the required market. This usually means that resources are limited and as we will show in our Giraff case study, this can have a major effect on the smooth running of the product development process. For example, halfway through the project, the original developers of the Giraff robot were declared bankrupt and a new owner had to take over. This implies that the development of a custom built software can take a long time to show a profit and is therefore it is difficult for non-established companies without large cash reserves to undertake a customisation project.

#### ***The evolutionary nature of improvements can be lost***

If the product under trial becomes unreliable due to resources and technology concerns, it could lead to reduced end-user involvement. This could mean that the feedback loop is overwhelmed with negative inputs.

#### ***The technology may not be generic***

The Giraff robot has reportedly worked well in its European trials [REF?]. However, we encountered significant difficulties in getting it to work reliably in an Australia context, where networks have lower bandwidth and higher latency.

### **PROBLEMS WITH THE GIRAFF TELEPRESENCE ROBOT**

The main problems encountered by the research team were:

- **Firewall issues:** The Giraff uses quite a complex network architecture, with a central directory server in Norway, a driving-commands server in Norway, plus a third-party video-conferencing protocol from a USA provider. For the Giraff to work correctly, several network ports are required to be open, to establish these connections and to ensure fast peer-to-peer video and driving control. However, in some environments we had no control over the firewalls we were using. For example, the Giraff would work fine within our University, but could not be accessed from outside the University, due to strict Eduroam firewall rules. In our Sunshine Coast case study, the network connection was via a dedicated 4G link into the Telstra network, and we had limited control over which ports were open, which probably contributed to the following problems.
- **Video Freezing:** This was the major problem with using the Giraff in Australia - the video frame rate would drop to zero frames per second (0 FPS) for 10-60 seconds, which made the Giraff impossible to drive. Usually the audio would freeze as well, which made communication impossible. We initially thought this was due to poor WiFi connectivity, and spent time trying to upgrade the Giraff's 802.11b USB Wifi adapter (which had no external aerial, and poor sensitivity) to a newer 802.11ac dual band Wifi adapter. This improved the Wifi bandwidth and range, but did not solve the video 0 FPS problems. Detailed network traffic investigation showed that the video and audio traffic was being routed via the USA, rather than peer-to-peer, so was often subject to intermittent lag and packet loss problems. We were unable to solve this problem reliably, due to lack of control over firewall rules, as mentioned above. So some days the video and audio would be fine, while other days the frame rate would go to zero and the Giraff would be unusable.
- **Driving Lag:** We encountered significant lag in the left/right driving controls, which made it difficult to control the Giraff. Detailed investigation of the network traffic with Wireshark showed that this was because the driving commands (UDP packets) were going via a server in Norway, with around 500msec lag. To overcome this we had to set up a UDP driving server in Australia.
- **Giraff offline:** The above problems meant that Giraff calls would quite often drop out, and this would leave the Giraff off-line for variable amounts of time (sometimes hours or days). This required using a secondary communication channel (email

or phone) to ask the primary user to reboot the Giraff, and sometimes, to manoeuvre it back to its charging station because the battery was flat.

### ***Adapted Solution – the Double robot***

The adapted solution invariably will not provide as much flexibility for customized end-user development, however it does offer a much more stable platform to work on and, given the problems outlined above could be a better option.

The benefits of an adapted solution are

1. The technology is stable and a commercial, established company will provide end-user good support
2. More resources will be available with respect to proven, commercialized hardware and software

The technology is stable and a commercial, established company will provide end-user good support

Purchasing products from a commercial, established company meant that the technical difficulties experienced by the Giraff robot did not exist for the Double. The technology was tried and tested and was really simply a combination of a Segway and an Apple iPad. This made interacting with the robot much easier. The video/audio communication protocols used by the Double seemed to be more resilient to firewall port-blocking problems than the Giraff, which is perhaps because the Double has been widely used in corporate environments. In addition, any problems we had were quickly sorted out through the company's support centre.

More resources will be available with respect to proven, commercialized hardware and software

The Double Robotics company did provide very good support and there was a general view amongst the research team that the level of support for the Double Robot was much more professional and speedier than that for the Giraff.

The downside of using an adapted solution could be;

1. User involvement and ownership in the product may not be as high as a customised solution as the product is commercially available and not specifically directed to the senior's market
2. Care providers may not have an opportunity to use the technology directly unless it is paid for.

User involvement and ownership in the product

User involvement in developing solutions could be less when dealing with older people due to a lack of incentives such as technology integration into the work place and peer pressure. The research team considered that the Giraff robot held an advantage with respect to user involvement because it was a dedicated product designed for solving the problem of social isolation and loneliness. However, this advantage was completely negated because the Giraff robot did not work.

### ***Care providers may not have an opportunity to use the technology directly unless it is paid for.***

The original Giraff project provided care providers to evaluate the technology for little cost as they did not have to pay for the robot, however the Double robot is a commercially developed device and will require payment to use the device even in a research environment.

### ***Problems with the Double Robot***

No specific technical problems have been encountered with the Double robot, however there are privacy issues. The Giraff had a knock feature which allowed the end-user to accept or reject calls. The double robot does not have this feature and the research team will have to find a workaround to solve this problem. This could involve the use of a second device (for example a mobile phone) to give some warning to the older person of an impending visit.

Conclusions

This research was conducted from a small University with very limited resources for research. The initial research approach was based on a need to assess the usability of telepresence robots in a home care setting and to this end aged care providers provided funding for the research to be undertaken. However, it quickly became apparent that the usability study would have to be postponed until various technical problems were overcome. This also meant that a significant component of the intended research budget had to go to troubleshooting technical problems.

The technical problems were often associated with both infrastructure problems specific to Australia and standards from other countries not being compliant to Australia's standards. An example of this was the medicine dispenser that was a part of the Giraff robot but could not be used in Australia. (Moyle et al. 2014)

The research team have been somewhat disillusioned with the Giraff robot and will have to abandon its usage. This is disappointing because the general principle of providing a richer communications environment for older people living independently was a worthy area of study that could have provided real benefits for individuals. The Giraff robot was assumed to be working and would hit the ground running thus allowing the research team to move directly into the usability studies that were the core of the project. However, the technical difficulties meant that this could not happen. As the other features of the Giraff

(fall detection and medicine dispensing) were either no longer functioning or would not be approved for use in Australia, it was decided that the Double telepresence robot was an equal comparative usage model to the Giraff.

Given the technical problems with the customised solution, the research team has continued the usability research with the Double robot. The purpose of this paper was to identify the problems associated with extending a research project from its European base to Australia with respect to unforeseen technical problems and to critically analyse the advantages of customised solutions versus adaption of commercial technologies. While the customised solution may have been the better option in previous, less technically demanding times, the research team considers the adaption of commercially available technology to be the better option when dealing with technology artefacts even in subject domains that are unique and very different to the mainstream (in our case aged care).

It is hoped that this paper can also assist future researchers who may have had the same objectives as our research team, namely simply testing the technology for usage and acceptance. However, the technology is evolving rapidly and there is a need to ensure the systems are working correctly in the chosen environment before even considering the implementation of usability and acceptance studies. We only wish we had the opportunity to assess the technical capabilities of the robot under Australian conditions before purchase and trialling.

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# Last Mile Delivery Using Drones

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## **Abstract**

*The UAVs, shortly called as Drones, have become the darlings of logistics industry. With its key capabilities of speedy delivery of goods, lower cost of operation and environment friendly technology, drones will have a bright market for logistics in future. Few logistics companies have already started investing in this technology and are operating on a small scale. In spite of its advantages, there are related issues associated with drone operations and maintenance. This paper focuses on the working mechanism of drones, applications of drone technology and related issues in the logistics industry.*

**Key words:** *Drones, UAVs, Logistics, Technology*

## **INTRODUCTION**

The concept of UAVs (Unmanned Aerial Vehicles) evolved from Austria in 1849 when they attacked Italy with flying balloons, and then by building drones during the 1st World War. The first drone was used in 1916, and the next during the Vietnam War. Drones were initially used for military missions, nuclear tests, and secret missions, and currently almost all countries own drones, usually used for medical purpose, policing and firefighting.

For the first time UAVs were used commercially in Japan in the beginning of 1980s, where unmanned helicopters were used, supplementing piloted helicopters to spray pesticides on rice fields, but remote aircraft technology was expensive and cumbersome. The advances in technological capabilities enabled drones to be used for meeting the supply chain requirements of many companies. The latest commercial models are capable of carrying lightweight packages such as medical supplies, books and food straight to the end-user by packing the goods in boxes and securely attaching straps (or limbs) located under the drone's rotors. Chinese company Alibaba was one of the first who launched drones delivery (Jason Reagau, 2015).

Drone technology applications are allowing companies to create new business and operating models for existing business processes, as each industry differs in its requirements, and hence requires different types of drone-powered solutions along with various drone functionalities.

## **LITERATURE REVIEW**

Very few reviews are available on the commercial use of drones for pick-up and delivery. Few economists have studied various commercial and civil applications of drones, covering wide range of topics and uses of drones, but focused only on aerial surveillance, and hence there is minimal published research on commercial drone usage for package delivery.

In their paper titled "Analysis of Unmanned Aircraft Systems and Application in the Civil Field", Kharchenko and Prusov (2012) considered various uses of drones by breaking them down into three groups namely safety control, scientific research, and commercial. They have highlighted various commercial uses, but did not explain the cargo delivery/transport. Their focus was mainly on aerial photography and surveillance opportunities. However, Kharchenko and Prusov do mention specific requirements needed in the structure of an Unmanned Aviation Complex (UAC) or drone station. These requirements are as follows:

- the unmanned aircraft itself;
- control stations (management) of unmanned aircraft and antennas system;
- software and systems of on-board monitoring of the unmanned aircraft;
- communication means (earth/air and air/earth) for air traffic control and unmanned aircraft payload;
- terminals of data processing;
- landing system;
- launch system and systems of the flight refreshment;
- maintenance equipment and the support of unmanned aircraft and its systems;
- systems of storage and transportation of unmanned aircraft complex.

Kharchenko and Prusov felt that as drone usage becomes more and more popular, problems may arise in the use of airspace and the allocation of frequency range for unmanned aircraft control and data transfer from the [aircraft] to the earth and vice versa. Similar to radio frequencies, competition over UAS frequency usage may become an issue that will need to be solved legally. They concluded that the market for drones and drone systems will expand in the future only when technical and administrative barriers are reduced.

Peter Tatham (2009) in his article “An Investigation into the Suitability of the Use of Unmanned Aerial Vehicle Systems (UAVS) to Support the Initial Needs Assessment Process in Rapid Onset Humanitarian Disasters” addresses the uses of UAVS in drones in providing aerial surveillance and reconnaissance in the areas that need immediate action. He quotes M. C. Christopher from Logistics and Supply Chain Management, saying, “there is broad agreement that timeliness of delivery is a key order-winning criterion,” before explaining how this is especially crucial to disaster zones (Tatham, 2009). Tatham believes that drones can lead to earlier and better quality aid to areas suddenly struck by a disaster.

Tatham uses his paper to analyze the benefits and downfalls of using manned versus unmanned methods of surveillance by discussing the differences in cost, data quality, and other requirements for each type of aircraft. The benefits of using a UAVS could outweigh the cost of developing and operating the technology. He explained that in the near future the cost of UAVS will become very inexpensive.

### WORKING MECHANISM OF DRONES

Two main types of electric drones are tested for delivery: multirotor drones (quadcopter/ hexacopter/octocopter) and hybrid drones. The multirotor drone is more popular given its maneuverability, and also it runs on batteries. Depending on the model, electric multirotor drones have an average maximum carrying capacity of 2 to 5 pounds, a maximum flying distance of 10 to 30 miles, top speed of 10 to 40 miles per hour, and a maximum flying altitude of 100 to 400 feet. These drones land for each delivery.

Hybrid drones, equipped with propellers and wings, can take off and/or land like a copter and can glide like a plane. This design increases the drone’s range. Some hybrid drones are designed to lower deliveries on a line, while others are designed to land. Most drones developed by Google, Amazon, and DHL use batteries.

### APPLICATIONS OF DRONE TECHNOLOGY

The total estimated value of drone powered solutions in all applicable industries as estimated by PwC is over \$127bn, with the infrastructure industry being on the top, with total addressable value of over \$45bn.

*Table –1: Value of drone powered solutions addressable industries – global view*

Industry	Value as of 2015 (\$ bn.)
Infrastructure	45.2
Transport	13.0
Insurance	6.8
Media & Entertainment	8.8
Telecommunication	6.3
Agriculture	32.4
Security	10.5
Mining	4.3
Total	127.3

*Source: Values presented in the table correspond with the value of businesses and labour in each industry that may be replaced by drone powered solutions, according to PWC research.*

Given the potential of the drone technology, the following are the areas in which they can be used:

#### **Transport**

The prospects for the increased use of drones in the transport industry are high due to the upcoming improvements in technology. Unmanned aerial vehicles are being used in a wide spectrum of transport activities, from e-commerce package delivery, to transport of medicines, to fleet management and spare-parts delivery and even to same-day food delivery. Drones are certain to become an integral part of the transport industry very soon, offering both a method of delivery and services accompanying transport.

### *Delivery of parcels*

In the e-commerce business, time of delivery is an important parameter in choosing a carrier. Drones enable fast delivery to a specific, predefined point, without much effort required. The convenience of sending packages to a client’s doorstep will create an improved customer experience.

Other areas of applications of drones are for delivery of spare parts, medications and food items.

### **DELIVERY DRONES FOR CARGO**

The use of unmanned drones for commercial package delivery has several advantages. One key advantage is speed. Since drones are not constrained by road infrastructure and congestion, they can deliver packages faster than a car/truck from a close-by storage location. Drones can traverse difficult terrain with relative ease and, in many cases, take a much shorter route. Drones can easily fly over water or rural areas with poor infrastructure to deliver a package. Delivery drones will have a reduced environmental impact, as they will result in fewer delivery trucks traveling on roads and polluting the atmosphere.

Given the potential benefits, it is not surprising that many delivery providers are testing drone delivery. One example is DHL, which launched a drone delivery service in September 2014 to get urgently needed goods such as life-saving medicines to Juist, an island in Germany’s North Sea where more traditional delivery options such as ferries or trains aren’t always available. Amazon has developed nearly a dozen aircraft as part of its Prime Air drone project and plans to develop a family of delivery drones to suit different environments. Google is testing drones that could deliver small packages in less than 30 minutes and has announced it will launch its drone delivery service in 2017. The table below provides a timeline of the evolving drone delivery landscape.

*Table – 2: Evolution of delivery drones*

<b>TIME FRAME</b>	<b>MILESTONE</b>
<b>2005 – present</b>	<b>Experimental delivery drones.</b> Companies such as Amazon, Google, UPS, DHL, and others have tested drone delivery for years, some since 2005.
<b>2014 – present</b>	<b>Commercial delivery drone pilots.</b> DHL launched its first commercial drone delivery for the German island of Juist in 2014. Matternet has been running drone deliveries in Switzerland, Haiti, and the Dominican Republic. Flirtey ran the first legal drone delivery for bottled water, food, and a first-aid kit in the United States on July 17, 2015. Amazon received FAA approval for research and development for drone delivery in 2015.
<b>2018</b>	<b>Widely permitted commercial delivery drones.</b> The FAA estimates that as many as 7,500 commercial drones may obtain drone permits from the FAA by 2018, provided that necessary regulations are in place.

### **DRIVERS & ENABLERS FOR COMMERCIAL APPLICATION OF DRONE TECHNOLOGIES**

#### *Developed and implemented regulatory frameworks*

Many organizations today are considering testing and using drones in their business operations, but need transparent rules on how and where to use them, to guarantee the safety and efficiency of their operations, and the grounds on which authorities issue licenses or permits for commercial drone applications.

National and international aviation authorities have started developing regulatory frameworks to guarantee the usage of drones in secure and business-friendly ways. The table below presents the regulatory framework in 15 countries, covering five continents.

*Table –3: Regulations by country*

Territory	Possibility of commercial flights	License required to fly	Possibility to perform BVLOS flights	License required for BVLOS flights	Insurance required for commercial flights	Training required for pilots in order to obtain licenses
Poland	√	√	√	√	√	√
UK	√	√	√	√	√	√
China	√	√	√	×	√	√

Canada	√	√	√	×	√	×
Germany	√	√	×	×	√	√
France	√	√	√	×	×	√
South Africa	√	√	√	×	×	√
Indonesia	√	√	×	×	√	√
Australia	√	√	×	×	√	√
Brazil	√	√	√	×	×	×
Mexico	√	√	×	×	×	√
USA	√	√	×	×	×	×
Japan	√	×	×	×	×	×
Russia	×	×	×	×	×	√
Argentina	×	×	×	×	×	×

Source: Based on PwC research (as of 31 March 2016)

### ***Enhancing data processing & accessibility***

Data acquired during drone operations has to be processed for delivering substantial value for business. The information have to be provided as fast as possible in an understandable, cohesive and comprehensive way. Customers expect the data to be available on every type of device (mobile or desktop), anytime, anywhere in the world, hence, data accessibility will be one of the key for faster adoption of drone technologies in business processes.

### ***New technological opportunities***

Drones consist of many technologically advanced parts, which affect their efficiency, safety and reliability. Improvements in hardware solutions and decreasing prices will increase the usage of drone applications, encouraging people to invest in this new, innovative and accessible technology. The development of new types of power sources, engines and structural materials will have an impact on the drone market potential. Manufacturers are developing hydrogen fuel cells, which are more efficient than the electric batteries that are currently used which could reduce weight and increase flight time.

Software and data processing is another field of technological improvement, in which the data obtained by the drone sensors, can be used to implement autonomous avoidance systems, to avoid collisions, and allow for automatic take-off and landing.

## **BARRIERS FOR COMMERCIAL APPLICATION OF DRONE TECHNOLOGIES**

### ***Safety of drone operations***

Ensuring secure supervision of recreational and commercial drone operations is the need of the hour. Safe supervision system requires developing a complex air-traffic management system for UAVs to prevent collisions with other flying objects, allowing UAVs to see and avoid other aerial vehicles and potential obstacles, and communicate with air traffic controllers of manned vehicles. It requires integration of these systems with national air traffic management systems for manned aviation, to ensure the flow of information. Drones also should possess auto-fail functions, preventing an uncontrolled fall from the air to the ground.

### ***Privacy issues***

Vast amount of data is collected when drone operators perform flights over certain types of sites, which includes confidential or sensitive information about private property or private behaviour. Due to a very broad definition of personal data, it isn't clear how companies should store these data, what types of data shouldn't be collected, or how individuals and companies can defend their privacy rights.

### ***Insurance coverage availability***

In most countries, aircraft users are obliged to have insurance to meet their liabilities in the case of an accident. Insurance would be an integral part of the complex regulatory framework, and is expected that it will be one of the main factors influencing risk management frameworks for drone technologies, in providing coverage for risks of physical losses or liabilities during and after drone operations.

While drones offer several advantages compared to traditional delivery methods, many limitations still lie ahead for them to scale. Drones currently have small shipping capacity; Global-positioning system (GPS) data can be inaccurate, affecting package drop-offs. With current technology, drones could drop off packages at the wrong house or over a swimming pool. Delivery drones may be considered as trespassers when they fly over the airspace above a person's private property and they can injure people who are subject to having drones flown over them. Given these risks, insurance costs for drone systems would increase their operating costs.

Hence, current FAA rules forbid drones from flying over people and require an on-the-ground observer to monitor the safety of the drone and people at all times when it is in operation. Commercial use of drones is permitted only if a business obtains a Section 333 exemption from the FAA, granted exclusively on a case-by-case basis.<sup>35</sup> Customer acceptance is another issue to consider, although a 2016 Temando survey found that 51 percent of customers are willing to accept a drone delivery in the future.

**ADVANTAGES OF CARGO DRONES**

***Save Money***

According to Bloomberg, human crews make up almost 50% of the cost of operating a cargo ship. If automation can save that amount of money, we expect a major trend toward cargo drones to arrive soon.

***Eliminate Human Error***

The possible errors that can be made by human beings, such as negligence, willful act, etc., can be eliminated by using the cargo drones.

***Deliver Goods to Places We Wouldn't Normally Go***

Remote areas of the world, such as oceanic islands, Arctic regions, or troubled or remote areas of Africa, are often inaccessible due to poor communications and transportation networks to those locations, where it's either too dangerous or too costly to ship goods there regularly. Unmanned aircraft or sea craft can perform these tasks efficiently in extreme conditions.

***Monitor & Protect Transportation Lanes***

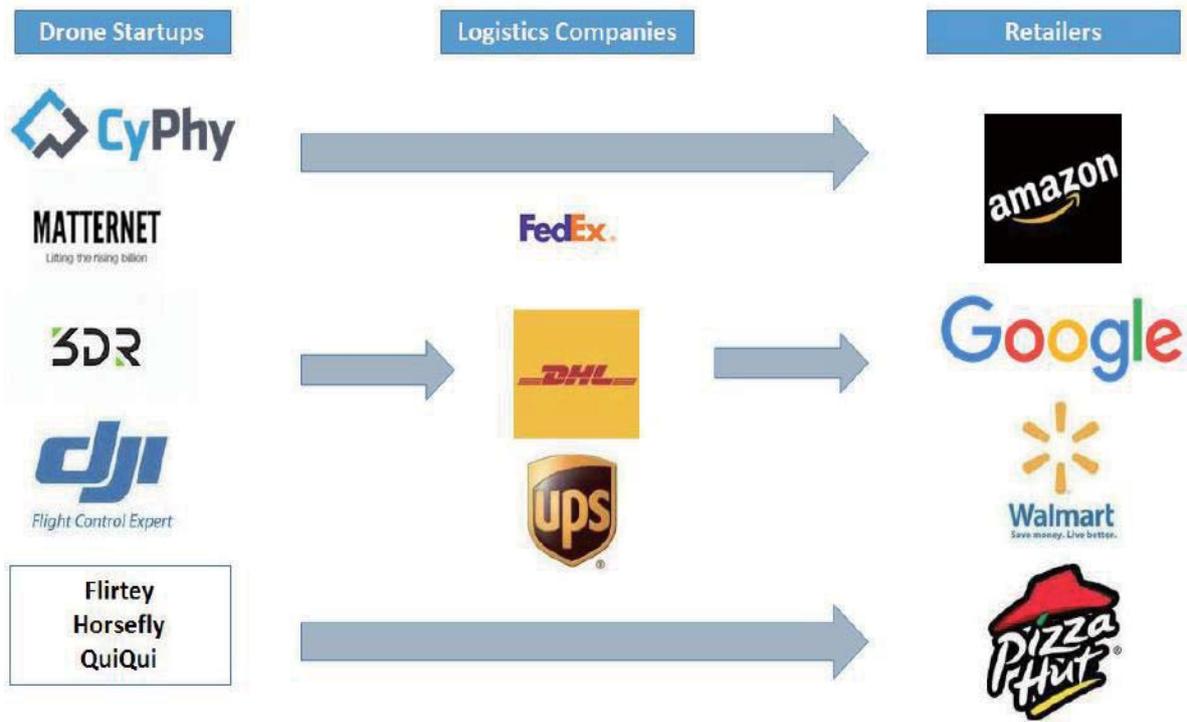
Companies, law enforcement agencies or safety organizations could use drones to monitor sea lanes for identification of potential pirates and keep the cargo safe by gathering information, capturing images while saving money and time over sending out a human-led patrol.

*Table - 4: Swot analysis of the global commercial and civil UAV market*

<p style="text-align: center;"><b>Strenghts</b></p> <p>Cost effective aerial transportation Carbon footprint reduction Access to remote areas Technological Innovations driven market</p>	<p style="text-align: center;"><b>Weaknesses</b></p> <p>Global aviation regulations need improvement Lack of unified international standards about crew certification, medical qualification, etc. High R&amp;D cost of UAVs equipped with the necessary specialized equipment</p>
<p style="text-align: center;"><b>Opportunities</b></p> <p>New emerging market Development of new UAV based services Market place for UAV software and SDK Flight endurance increase with solar power</p>	<p style="text-align: center;"><b>Threats</b></p> <p>Slow harmonization process of global aviation regulations for UAV operation New technology, which is not well tested and may have higher failure rate Strong influence of NGOs and social organizations</p>

**CURRENT PLAYERS IN THE DRONE MARKET**

According to a research report from Radiant Insight, Unmanned aerial systems (UAS) market at \$609 million in 2014 is forecasted to reach \$4.8 billion dollars worldwide by 2021, with oil and gas mapping, utility line inspection, package delivery, and agricultural applications accounting for virtually all the unit sales. Drones can provide more information at less cost than a human inspection team can.



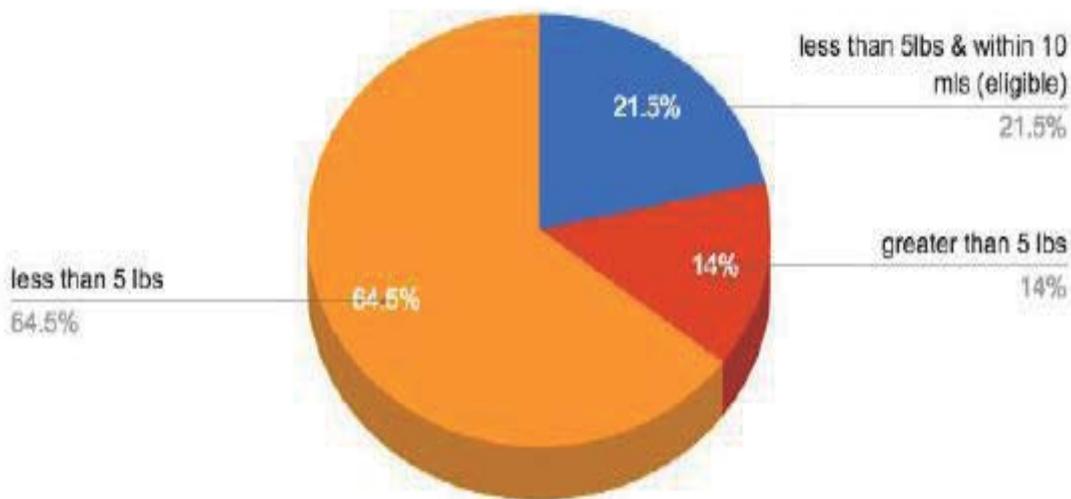
**Retailers**

**Amazon**

Amazon is the largest online retailer with revenue of 88.9B in 2014. It is advancing in experimenting with drones for package delivery by proposing “Amazon Prime Air” and is working with FAA for regulatory and safety standards. Amazon Prime Air is designed to deliver packages via a drone in just 30 minutes. Amazon is thinking beyond just home delivery and already has design for features like ‘Bring it to Me’, which captures a customer’s location by GPS data received through mobile devices. Amazon has been granted experimental rights by FAA in March 2015, which indicates that drones can only be flown at 400 feet or below during the day in clear weather conditions, and must remain in the line of sight of their operators, who must hold at least a private pilot’s certificate and medical certification.

Current drone technology can handle packages of up to 5 lbs. The chart below shows that 21.5% of total packages delivered by Amazon are eligible to be delivered by drones (Keeney 2015).

*Chart – 1: Packages delivered by Amazon*



Source: Keeney, Tasha. "How can Amazon Charge \$1 for Drone Delivery?" Ark Invest, May 5, 2015

### Google

In Aug 2014 Google revealed that it has been working on drone delivery for the last 2 yrs. The project is called ‘Project Wing’ run by Google X, the company’s research lab. It has been running experiments in Australia as their regulations around UAVs are much more permissive than the U.S. During this initial phase of development, Google landed on an unusual design called a tail sitter, a hybrid of a plane and a helicopter that takes off vertically, then rotates to a horizontal position for flying around. For delivery, it hovers and winches packages down to the ground. At the end of the tether, there’s a little bundle of electronics, which detects that the package has hit the ground, detaches from the delivery, and is pulled back up into the body of the vehicle.

### Other Retailers - Delivery and Logistics Companies

There are many other online retailers who could partner with a logistics company that provides drone deliveries.

### FedEx

FedEx has acknowledged that it had conversations with drone manufacturers for drone delivery, but is yet to take off to adopt the new technology.

### UPS

In 2013, sources familiar with the company’s plans said it has been testing and evaluating different approaches to drone delivery, but is skeptical and does not think that it will catch on soon as mainstream delivery mechanism.

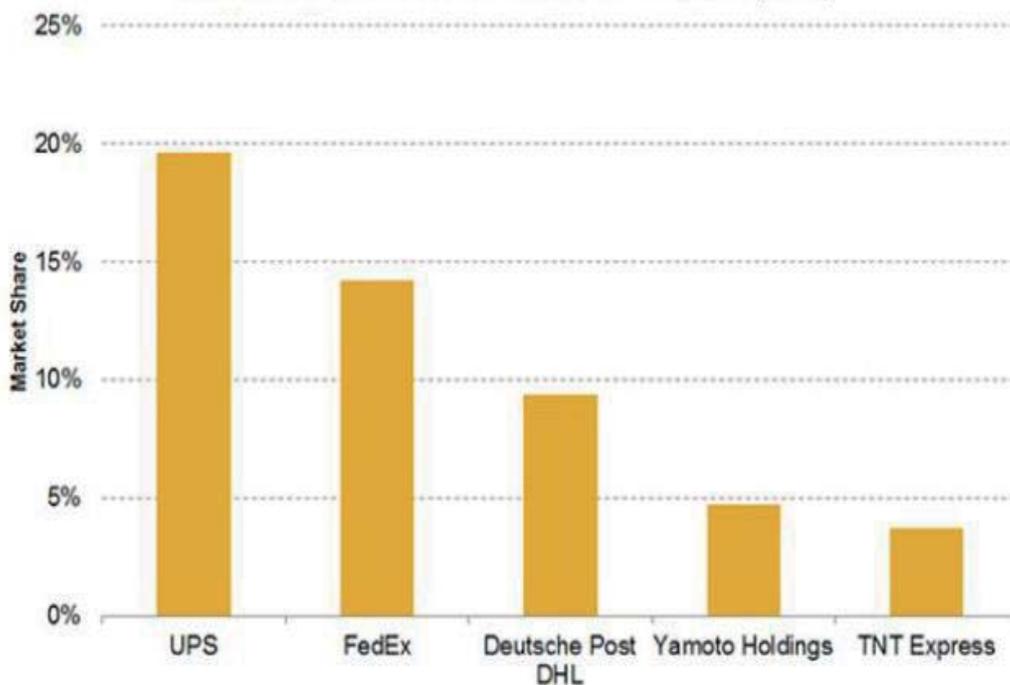
### DHL

DHL Express launched a helicopter styled drone, "parcel copter", which will deliver medications and other urgently needed goods to the remote North Sea island of Juist. DHL will operate the parcel copter on a regular basis, initially on a research basis.

### AMP Holdings

In June 2014, AMP Holdings announced that it had successfully designed and developed a prototype of HorseFly, a battery operated UAV, which can be combined with the workhorse trucks to deliver packages.

Chart – 2: Market share of courier service providers (2014)

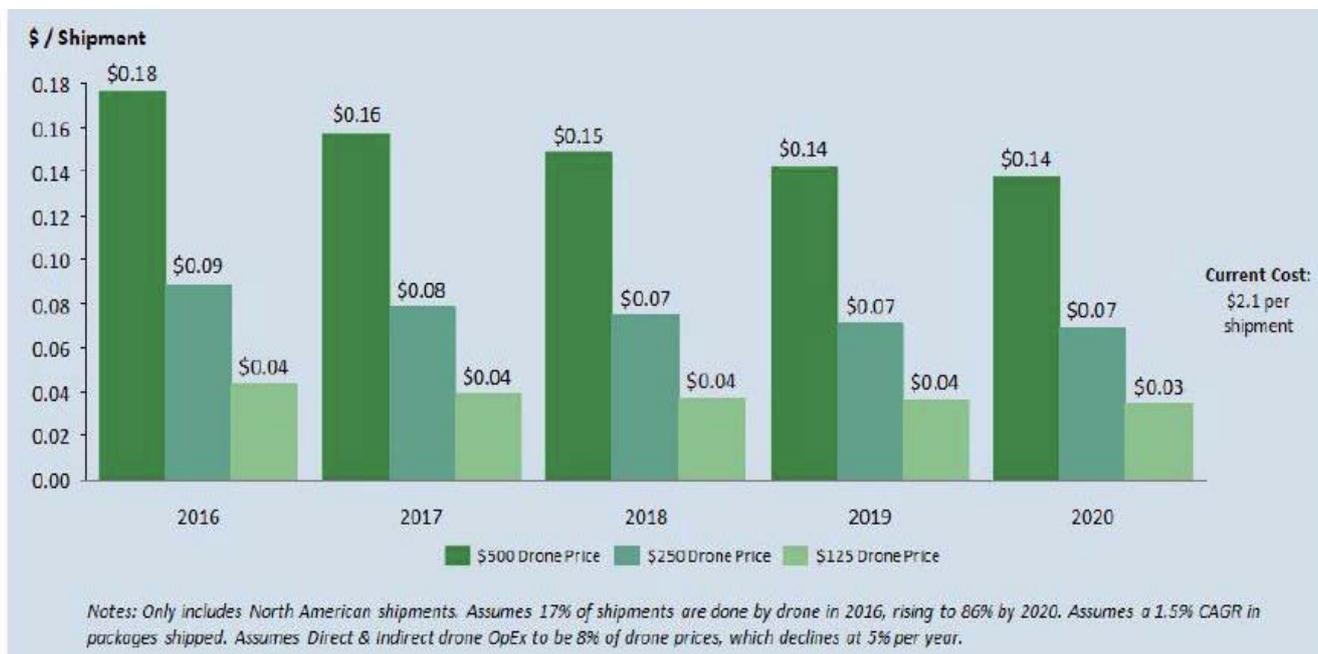


Source: Schmidt, Ally. “A Look at the Courier Service Industry in the United States”, Market Realist, July 17, 2015

The cost savings created by drone deliveries can be passed on to consumers, because it costs far less to operate a fleet of unmanned aerial vehicles than to operate a fleet of ground vehicles. It costs 10 cents to deliver a 4.4 pound (2 kilo) package over six miles (9.7 kilometers) using a drone, which is far cheaper than the \$2 to \$8 per package that it costs Amazon today using ground transportation

for deliveries over this last mile. Offering 30minute delivery at such a low cost to consumers could boost the ecommerce and retail market industry.

Chart – 3: Projected cost per drone shipment (\$/shipment)



Source: Menon, Prashob. Ivey Business Review. December 11, 2013

## KEY ISSUES IN DRONE MAINTENANCE AND SUPPORT

### Battery

The current disadvantage for transportation drone is battery life. Currently commercial drone batteries offer about 10 to 20 minutes of flight time, and it further gets reduced based on the shipment weight. But, this limitation has not prevented drone companies from innovating solutions to extend transport range.

### Management and monitoring

Drone management and monitoring is in process with multiple companies providing comprehensive autonomous transport solutions, which extend from simple OEM components to complete centralized management suites, which can include the following categories:

- Integrated flight planning
- Air traffic management
- Automated regulatory compliance
- Flight operation logging and reporting
- Asset management

### Complete solutions

Apart from supplying an autonomous drone for light transportation, the OEMs are providing a centralized cloud based flight planner by using existing information about restricted airspaces, ground topology, population density, weather and building location. Once the delivery package is on its way, the OEM will notify the package receiver of the flight status and when the package has been delivered.

### OEM's

Several drone OEM suppliers, some of which are providing hardware components that are used on every variety of drones. They are looking into the future for integrated drone solutions to solve the drone air traffic problem by using cellphone networks to communicate with a centralized drone air traffic control system, which in turn be able to establish a direct link with the drones and communicate new flight instructions if required to avoid collisions or reroute with a new flight plan.

### Technology outlook

The drone industry is expected to get clearance from FAA for pilotless drones and package delivery along with air traffic controlled delivery. This requires the following technologies:

Heavy rain resilient and withstand damage from bad weather and animals

Automated regulatory compliance

Autonomous accident avoidance while flying at high speeds

Direct Drone Communications using cellular networks

## **FUTURE PROSPECTS FROM DELIVERY DRONES**

Until now, helicopters have distinguished themselves from airplanes by their flight flexibility. Drones not only provide the same opportunities, but have the advantage of being smaller and eliminating the risk of losing a human operator. Another big advantage is their price, and therefore their extremely high availability. Thus, it is reasonable to forecast that drones will decrease the need for helicopters, and be able to conduct operations where the use of helicopters was too expensive or dangerous. On the other hand, if the two sectors merge, new opportunities may arise.

Drones are small in size and cannot transport heavier objects. Hence, it is expected that, in future, other types of drones, such as cargo drones, which are unmanned and are operated on autopilot or remote control, will be ready to deliver goods at lesser cost. Companies like Rolls Royce are investing to develop these models, which would be more environment friendly, less expensive to operate and carry most of the cargo.

Several technologies are improving the safety of unmanned commercial drones by providing better visibility to surroundings. One of them is the automatic dependent surveillance-broadcast (or ADS-B) technology, which determines an aircraft's own position in space via satellites and periodically broadcasts its position and direction. While ADS-B is already in use for manned commercial aviation, new innovations are making ADS-B units sufficiently small and inexpensive so that they can be placed on unmanned drones as well. Another innovation is a sense-and-avoid situational awareness technology, which allows the drone to scan its surroundings so it can identify and avoid obstacles in the air and while taking off and landing.

## **CONCLUSION**

Traditional delivery companies, new entrants to the market, as well as merchants themselves could use drones to offer same-day delivery services by satisfying customers' desire for speedy delivery in an environmentally friendly way. Intermediary companies could save costs by having their workforce focus on shopping for customers while using drones for the actual delivery. If the cost to own and operate a highly functional drone becomes sufficiently low so that individual people could own drones for personal product transport, customers could potentially send their drone to the store to fetch their orders. Though the use of drones will be limited to a certain delivery distance and package size, the market potential is high. Drones can provide a convenient solution for delivering urgently needed items to remote or hard-to-reach locations.

As the drone technology evolves and the associated risks are resolved in the future, it is expected that regulations will become less strict, and beyond visual line-of-sight technology may be permitted by new commercial drone regulations that the FAA is working to finalize by 2017. Above all, the uncertainties regarding regulations will impact the cost estimates of drone delivery operations.

Once the technological limitations are resolved, regulatory restrictions are relaxed, and public concerns around safety and privacy are addressed and minimized, drones could have a significant impact on the landscape of last-mile delivery.

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# Transportation Network Modeling - The Optimal Route from Single Origin to Single Destination

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## ABSTRACT

The present paper aims to discuss a transportation optimization network problem. The field of network optimization concerns optimization problems on networks. The authors deem that the network models merit discussion as the applications of network optimization are many, as to industrial logistics, supply chain management and a variety of systems. In particular, the weighted shortest path problem is a broadly useful problem-solving model. Furtheron, an example of application of multi-attribute utility, namely the choice of optimal route in a city street network is considered. For analytic description of the considered problem it is applied the multi-attribute utility theory. The paper proposes consideration of specific factors in the network modeling decision making. For determination of the weighted coefficients in the model, in order to be found the optimal route from single origin to single destination, is applied a heuristic approach.

## KEYWORDS

Network transportation modeling, weighted shortest path problem, multi-attribute utility function

## INTRODUCTION

The present paper discusses a transportation optimization network problem. The field of network optimization concerns optimization problems on networks. Among others, the weighted shortest path problem is a broadly useful problem-solving model. The authors find it very important to propose consideration of additional factors influencing the weighted coefficients in the network modeling decision making.

The paper is structured in five sections. Besides the Introduction part, in Section 2 the paper presents a background on the weighted shortest path problem. Consecutively, in Section 3 the authors explain the proposed methodology and consider one example of application of multi-attribute utility, namely the choice of optimal route in city street network. The expediency of the choice of route in the city depends on the overloading of the individual street segments, the presence of speeding lanes, presence of large crossroads, current repairs on the road, etc. By taking into account these factors, the problem becomes multi-criteria one. For analytic description of the considered problem it is applied the multi-attribute utility theory. Finally, the paper draws conclusions and future research directions.

## PROBLEM DEFINITION

Many companies face the transportation problem to deliver goods from point A to point B in a city – usually there is more than one route to go. We will take into consideration such a case in Sofia as shown on Figure 1. The application of Linear Programming (LP) is a good solution in that case. The problem we set is that there are many traffic jams in the city and the shortest path criterion is not always the best solution.

However, with development of the Smart City a big massive of data from traffic lights becomes available. It is of great advantage this data to be stored in a cloud environment, in machine-readable format (csv, xml, JSON) in real time so it can be used in solving such transportation problem. Currently, we have data collected from 38 main and complicated traffic lights in Sofia in a certain time frames.

We developed a general model for that kind of transportation problem and prove it using the available static data. The model could be modified so that to use dynamic (real time) data once it becomes available.

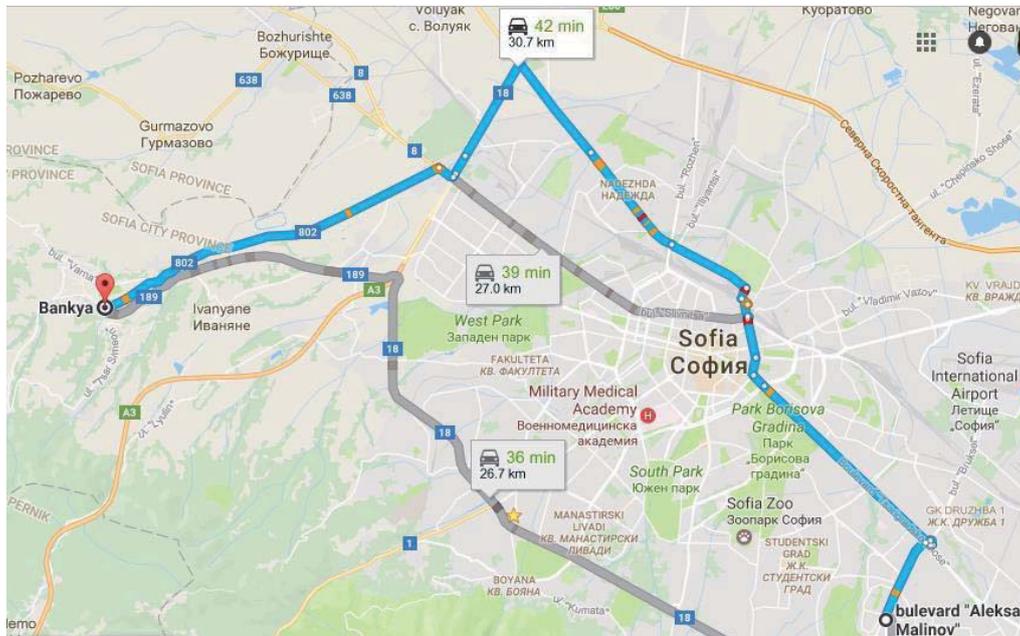


Figure 1. Google maps suggests three paths from district Bankya (point A) to district Mladost 4 (point B) in Sofia

### BACKGROUND ON THE WEIGHED SHORTEST PATH PROBLEM

Network optimization has always been a core problem domain in computer science, applied mathematics, and other fields of engineering and management.

The shortest path problem consists of finding a path between two vertices (or nodes) in a graph such that the sum of weights of its constituent edges is minimized. In other words, the shortest path problem consists in finding a path from A to B having minimum total length. There are many papers in the literature that are discussing driver's route choice behavior and a robust optimization approach for dynamic traffic signal control with emission considerations, optimization method for sustainable traffic control in urban areas, or presenting a comparative analysis of multi-criteria road network as well as a multi-criteria optimization of traffic signals: mobility, safety, and environment, etc.

For example, drivers' choice of route is usually personalized and is multi-criterial choice. So that, the urban shortest path problem is the personalized urban multi-criteria shortest path problem. For the sake of solving such a problem, a new stochastic optimization algorithm based on the iterative calculation of a valid route set is proposed in a paper by Bowen and Ciyun (2015). The effective and reasonable path searching mechanism is based on drivers' habits for route choice. The authors present evaluation method of calculation results. The comparative experimental results with the genetic algorithm show that the proposed algorithm has provided better results in the evaluation parameters and computing time. The experimental results also demonstrate that it is feasible to consider drivers' travel law in the personalized urban multi-criteria shortest path algorithm in order to avoid obtaining impractical routes solutions (Bowen and Ciyun, 2015).

Travel optimization is method to find the best route to be followed for a trip between two points. This optimization can be based on factors considered important while traveling.

The work by Qureshi et. al. (2013) deals with design of a multi-criteria based traffic network evaluation technique, using different methods to calculate the cost of the feasible set of solutions and then to decide which path is most desirable for a given requirement domain.

Various forms of the desired results e.g. the global depths of all the nodes in a given road network are extracted and presented, and compared by implementing the different methods of cost calculation: a weight based method and a fuzzy logic based mechanism. Both methods used are compared through a case study Among the aims of this research is to develop a way of solving the multi objective optimization problem of finding the shortest path using some optimization methods for given multiple objectives. The phenomenon of multiple criterions explains the nature of the problem while increasing one or more objectives reduce effect of the rest of the criteria, which effectively makes the solution more complex but comes out with better results and provides more knowledge of the problem itself.

The optimization of traffic signalization in urban areas is formulated in Papatzikou et. al. (2015) as a problem of finding the cycle length, the green times and the offset of traffic signals that minimize an objective function of performance indices. Typical approaches to this optimization problem include the maximization of traffic throughput or the minimization of vehicles' delays, number of stops, fuel consumption, etc. Dynamic Traffic Assignment (DTA) models are widely used for online and offline applications for efficient deployment of traffic control strategies and the evaluation of traffic management schemes and policies. The authors propose an optimization method for combining dynamic traffic assignment and network control by minimizing the risk of potential loss induced to travelers by exceeding their budgeted travel time as a result of the traffic signal settings, using the Conditional Value-at-Risk model. The proposed methodology can be easily implemented by researchers or practitioners to evaluate their alternative strategies and help them to choose the alternative with less potential risk. The traffic signal optimization procedure is implemented in TRANSYT-7F and the dynamic propagation and route choice of vehicles is simulated with a mesoscopic dynamic traffic assignment tool (DTALite) with fixed temporal demand and network characteristics. The

proposed approach is applied to a reference test network used by many researchers for verification purposes. Numerical experiments provide evidence of the advantages of this optimization method with respect to conventional optimization techniques. The overall benefit to the performance of the network is evaluated with a Conditional Value-at-Risk Analysis where the optimal solution is the one presenting the least risk for 'guaranteed' total travel times.

As a result of the continuous increase of motor vehicles in city areas, sustainability of road traffic in terms of energy and emission has become, in addition to mobility, one important aspect in the planning and management of transportation. Ma (2012) introduces a computational framework to model traffic impacts and optimize traffic control measures by integrating microscopic traffic simulator with instantaneous emission model and multi-objective evolutionary algorithm. The approach is applied for evaluation and improvement of traffic management measures mainly traffic signal plans, concerning not only travel delay but also energy and environmental consequences. A case study is presented to show the Pareto frontiers estimated using different strategies, or combination of optimization objectives.

Two-dimensional multi-objective optimizations have been used for decades for the problems in traffic engineering although only few times so far in the optimization of signal timings.

While the other engineering and science disciplines have utilized visualization of 3-dimensional Pareto fronts in the optimization studies, not many of those concepts are applied to traffic signal optimization problems. To bridge the gap in the existing knowledge Stevanovic et. al. (2015) present a methodology where 3-dimensional Pareto Fronts of signal timings, which are expressed through mobility, (surrogate) safety, and environmental factors, are optimized by use of an evolutionary algorithm. The study uses a segment of 5 signalized intersections in West Valley City, Utah, to test signal timings which provide a balance between mobility, safety and environment. In addition, a set of previous developed signal timing scenarios, including some of the Connected Vehicle technologies such as GLOSA, were conducted to evaluate the quality of the 3-dimensional Pareto front solutions.

The results show success of 3-dimensional Pareto fronts moving towards optimality. The resulting signal timing plans do not show large differences between themselves but all improve the signal timings from the field significantly. The commonly used optimization of standard single-objective functions shows robust solutions. The new set of Connected Vehicle technologies also shows promising benefits, especially in the area of reducing inter-vehicular friction. The resulting timing plans from two optimization sets (constrained and unconstrained) show that environmental and safe signal timings coincide but somewhat contradict mobility.

Tsaggouris and Zaroliagis (2007) provide an improved FPTAS for multiobjective shortest paths—a fundamental (NP-hard) problem in multiobjective optimization—along with a new generic method for obtaining FPTAS to any multiobjective optimization problem with *non-linear* objectives. The authors show how these results can be used to obtain better approximate solutions to three related problems, multiobjective constrained [optimal] path and non-additive shortest path that have important applications in QoS routing and in traffic optimization. They also show how to obtain a FPTAS to a natural generalization of the weighted multicommodity flow problem with elastic demands and values that models several realistic scenarios in transportation and communication networks.

Andy and Chow (2015) present an optimisation framework for motorway management via ramp metering and variable speed limit. The authors start with presenting a centralised global optimal control problem aiming to minimise the total travel delay in a motorway system.

Given the centralised global optimal control solutions, they propose a set of decentralised ramp metering and speed control strategies which operate on a novel parsimonious dynamic platform without the need of underlying traffic model. The control strategies are applied to a case on UK M25 motorway. The results show that the proposed set of decentralized control is able to deliver a performance that is close to the global optimal ones with significantly less computational and implementation effort. This study provides new insights to motorway management.

## THE PROPOSED METHOD FOR FINDING THE OPTIMAL WEIGHTED ROUTE

The data sets that we analyze are from the traffic monitoring system in the city of Sofia (from video cameras or inductive frames) namely for the traffic lights on the road of interest. We performed data analyses on the static data and based on the queries that were recognised in the data we determine the weighted coefficients in the optimization function.

Figure 2 shows a graph which represents the three possible ways that Google maps proposes to choose between in order to go from point A to point B as it is shown on Figure 1. We assume that the weights  $x_{ij}$  are a function of different parameters as given in Eq. 1 below.

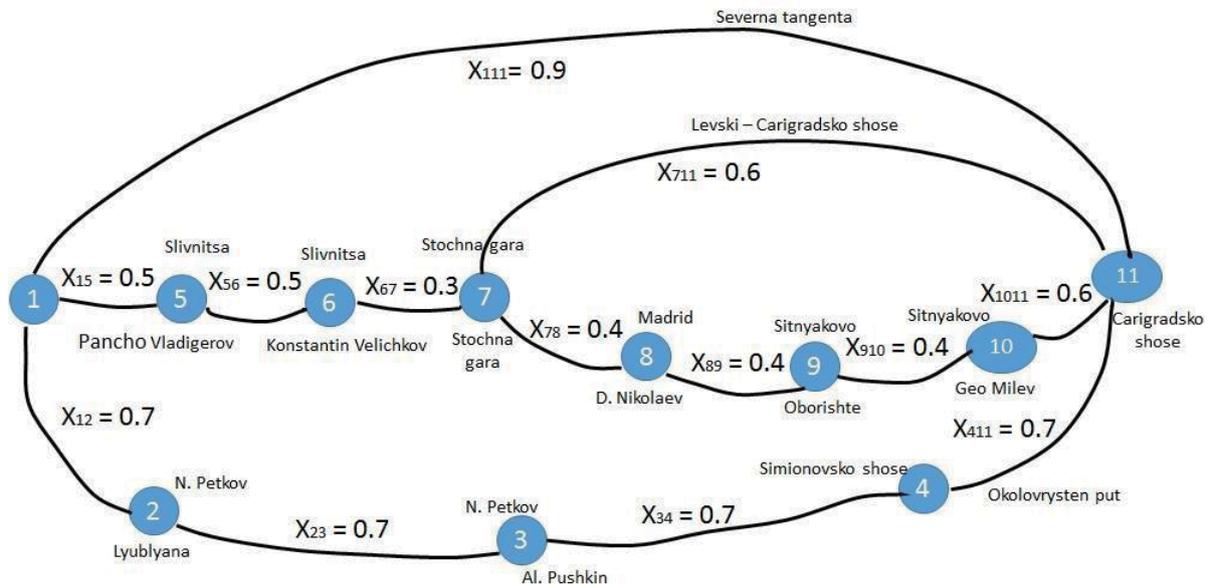


Figure 2. The graph presentation of the three suggested paths from Bankya (as point A) to Mladost 4 (as point B). The nodes are traffic lights for which we have collected data

A heuristic approach is applied in determining the weights in the model for finding the optimal route from single origin (point A) to single destination (point B), as shown in the function below:

$$x_{ij} = f(z_1, z_2, z_3, z_4, t) \tag{1}$$

where

$z_1$  is the number of traffic lights from point A to point B

$z_2$  is the length of route

$z_3$  is condition of the road covering

$z_4$  is the length of queue of vehicles at the traffic light

$t$  is the time during the day. In case the data is static, it is important to be taken into consideration if it is gathered during pick hours.

The coefficients are calculated as fixed on the base of the static data from the traffic lights that we have available. Furtheron, we solve the classical task of LP by performing the following transformations:

$$\begin{aligned}
 x_{111} &\equiv x_1 \text{ and } c_1 = 0.9 \\
 x_{12} &\equiv x_2 \text{ and } c_2 = 0.7 \\
 x_{15} &\equiv x_3 \text{ and } c_3 = 0.5 \\
 x_{23} &\equiv x_4 \text{ and } c_4 = 0.7 \\
 x_{56} &\equiv x_5 \text{ and } c_5 = 0.5 \\
 x_{67} &\equiv x_6 \text{ and } c_6 = 0.3 \\
 x_{34} &\equiv x_7 \text{ and } c_7 = 0.7 \\
 x_{78} &\equiv x_8 \text{ and } c_8 = 0.4 \\
 x_{711} &\equiv x_9 \text{ and } c_9 = 0.6 \\
 x_{89} &\equiv x_{10} \text{ and } c_{10} = 0.4 \\
 x_{910} &\equiv x_{11} \text{ and } c_{11} = 0.4 \\
 x_{1011} &\equiv x_{12} \text{ and } c_{12} = 0.6 \\
 x_{411} &\equiv x_{13} \text{ and } c_{13} = 0.5
 \end{aligned} \tag{2}$$

The objective function is as follows:

$$c_1x_1 + c_2x_2 + c_3x_3 + c_4x_4 + c_5x_5 + c_6x_6 + c_7x_7 + c_8x_8 + c_9x_9 + c_{10}x_{10} + c_{11}x_{11} + c_{12}x_{12} + c_{13}x_{13} \rightarrow \min \tag{3}$$

With the following constrains:

$$\begin{aligned}
 x_i &\geq 0 \\
 x_1 + x_2 + x_3 + 0 + 0 + 0 + 0 + 0 + 0 + 0 + 0 + 0 + 0 &= 1 \\
 0 + x_2 + 0 - x_4 + 0 + 0 + 0 + 0 + 0 + 0 + 0 + 0 + 0 &= 0 \\
 0 + 0 + 0 + x_4 + 0 + 0 - x_7 + 0 + 0 + 0 + 0 + 0 + 0 &= 0 \\
 0 + 0 + 0 + 0 + 0 + 0 + x_7 + 0 + 0 + 0 + 0 + 0 - x_{13} &= 0 \\
 0 + 0 + x_3 + 0 - x_5 + 0 + 0 + 0 + 0 + 0 + 0 + 0 + 0 &= 0
 \end{aligned}$$

$$\begin{aligned}
0 + 0 + 0 + 0 + x_5 - x_6 + 0 + 0 + 0 + 0 + 0 + 0 + 0 + 0 &= 0 \\
0 + 0 + 0 + 0 + 0 + x_6 + 0 - x_8 - x_9 + 0 + 0 + 0 + 0 + 0 &= 0 \\
0 + 0 + 0 + 0 + 0 + 0 + 0 + x_8 + 0 - x_{10} + 0 + 0 + 0 + 0 &= 0 \\
0 + 0 + 0 + 0 + 0 + 0 + 0 + 0 + 0 + x_{10} - x_{11} + 0 + 0 + 0 &= 0 \\
0 + 0 + 0 + 0 + 0 + 0 + 0 + 0 + 0 + 0 + x_{11} - x_{12} + 0 + 0 &= 0 \\
x_1 + 0 + 0 + 0 + 0 + 0 + 0 + 0 + 0 + x_9 + 0 + 0 + x_{12} + x_{13} &= 1
\end{aligned}
\tag{4}$$

So that, the optimal path (minimum) is  $x_{111}$ .  
When  $c_1 = 3.9$  instead of  $c_1 = 0.9$ , then the optimal path is as follows:

$$x_{15} \rightarrow x_{56} \rightarrow x_{67} \rightarrow x_{711}
\tag{5}$$

In case the data from traffic lights is not available, it is possible to solve the problem applying the multi-attribute utility theory (Pavlov and Andreev, 2013).

On the other hand, when data from traffic lights is available in real time (online), it is possible to solve the problem of finding optimal path from point A to point B having a traffic light following the procedure of the calculation logic presented in Figure 3.

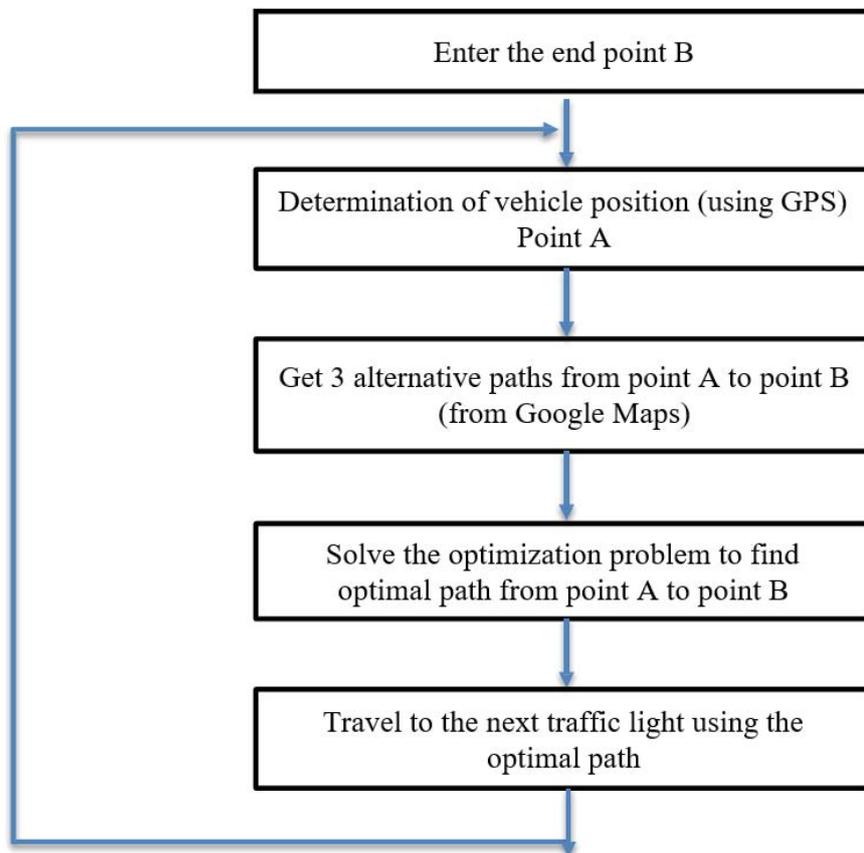


Figure 3. Calculation logic with real time data from traffic lights

It is possible to be built a web-based solution that helps to navigate through the city using real time traffic data from traffic lights or based on the expert knowledge of experienced drivers using utility function. Again, data from traffic lights must be available in real time in machine-readable format in a cloud storage. The Excel solver available for linear programming problem should be also placed in a cloud. The proposed here heuristic calculation of weights is a private solution. Google maps API is publicly available as well as a GPS positioning. The structure of the proposed web solution is presented in Figure 4.

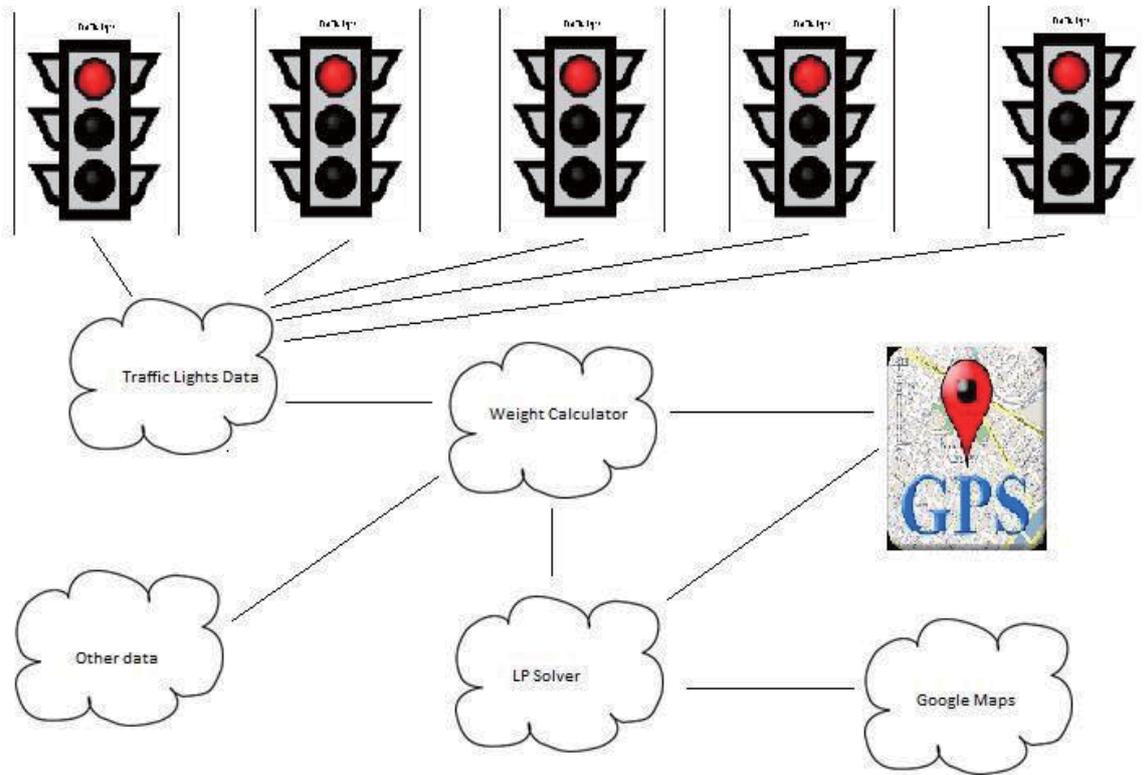


Figure 4. Structure of a web-based solution

## CONCLUSION

The present paper deals with transportation optimization network problem, in particular the expediency of the choice of route in the city depends on the overloading of the individual street segments, the presence of speeding lanes, presence of large crossroads, current repairs of the road, etc. It is proposed a model for solving the stated problem with static data. In case of dynamic data, the weighted coefficients in the model will be variable depending on the data dynamics at a given moment. Therefore, the best possible route from single origin to single destination also will differ based on those weights. So that, a web-based solution for optimal transportation in a city with available real time data from traffic lights has been proposed. Authors will focus a future research on solving the problem with dynamic data in a Cloud environment. The model could be revised so that the drivers becomes independent from the regulations taken by the Municipality about the road information. It is also interesting to be applied similar concepts on a variety of networks and traffic conditions before generalizing findings. A web based solution will be also built.

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# Why People Decide to Buy via Social Network Sites

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## ABSTRACT

Social commerce is a new form of social media-mediated commerce that allows customers to participate actively in the marketing and selling of products in online marketplaces. Even though social commerce has become a crucial topic and academics have begun to invest considerable effort in understanding why customers use social media, fewer studies have investigated design features in social commerce. Applying a stimulus–organism–response model, this study investigated the influences of social commerce sites on customers’ virtual experiences and on social shopping intentions. The findings indicated that social commerce constructs exerted a positive and significant effect on cognitive and affective states of social interactions. Besides, social presence and informational support influenced intention to trust in product recommendation. Social support exerted a significant effect on familiarity. Familiarity exerted a positive and significant effect on closeness, which further exerted a positive and significant effect on trust in product recommendation. Finally, trust in product recommendation exerted a significant effect on social shopping intentions. The findings explain how customers use social network sites in aiding purchasing decision that help online vendors in understanding products when they are developing their advertising and promotion strategies.

## KEYWORDS

Social commerce constructs, Stimulus–organism–response (SOR) model, Trust

## INTRODUCTION

Social commerce is a new form of social media-mediated commerce that allows customers to participate actively in the marketing and selling of products in online marketplaces (Huang and Benyoucef, 2015; Shadkam and O’Hara, 2013). Social media such as Facebook and Twitter provide unparalleled platforms and functions by which their users can publicize their personal evaluations of purchased products within social networks (Shadkam and O’Hara, 2013). Compared with recommendations or reviews on shopping platforms provided by merchants, customers prefer to share their purchasing and consumption experiences on the shopping platforms of social networking sites because users in social networks are friends or indirect acquaintances and their information sharing seems relatively real and accurate (Bai *et al.*, 2015). Because social commerce has evolved quickly in practice, it has not been studied as extensively as e-commerce and social media (Curty and Zhang, 2013). Because the concept of social commerce is new, scant research describes social commerce or reveals its characteristics (Kim and Park, 2013). Although social commerce is a subset of e-commerce, the concept of social commerce must be distinguished from other established concepts of e-commerce (Yadav *et al.*, 2013). For example, in conventional e-commerce, customers may distrust reviews provided by unknown online shoppers while trusting information shared by friends on social networking sites. Although a plethora of findings are relevant to e-commerce, social commerce remains an area requiring further validation (Alshibly, 2014). In addition, social commerce has become a crucial topic and academics have begun to invest considerable effort in understanding why customers use social media (e.g., Wang and Chou, 2014; Ng, 2013; Zheng *et al.*, 2013), but fewer studies have investigated design features in social commerce. Many questions regarding how customers use social features and what facilitates or hinders customers’ use of social commerce sites remain practically unanswered (Ellahi and Bokhari, 2013). For example, Gonçalves Curty and Zhang (2013) reported that few systematic investigations discuss how retailers’ websites incorporate technical features over time to support social commerce strategies. Therefore, this study investigates the critical roles of social commerce features and constructs.

Various aspects of environmental stimuli affect peoples’ internal states or organismic experiences. In the present study, social interactions are used to represent customers’ internal processes because social commerce is driven by social interactions through social networking sites. Social interactions enable customers to obtain information about products, services, and other experiences associated with transactions. Lin and Lu (2011) suggested that the spirit of social networking sites emphasizes user interaction and involvement. However, Kolesar and Galbraith (2000) determined that online retailers have difficulty satisfying customers’ needs, such as personal interaction. Little is known about how interactions happen on social commerce sites, how customers interact within social commerce sites (Shin, 2013), or why people use social media to gather information (Chung and Austria, 2010). Trust is defined as a willingness to rely on friends in whom a customer has confidence (Shin, 2013). Trust is also used to represent customers’ internal processes because trust has been shown to be a critical factor in internet-based customer behavior. However, Li *et al.* (2013) mentioned that e-commerce platforms generally do not consider social factors, such as trust, among the users. Therefore, social interaction and trust can be used to explore customers’ internal processes. Response is associated with customers’ behavioral reactions. In the context of online shopping, response to stimuli is often termed a “behavioral intention.” The popularity of online social networks has driven buyers’ purchasing decisions on social commerce sites (Kim and Srivastava, 2007). Benefits resulting from social interactions and user contributions have attracted customers to use social commerce sites (Liang and Turban, 2011/2012). This study applies the stimulus–organism–response (SOR) model (Mehrabian and Russell, 1974) to investigate the characteristics of social media sites characteristics that influence customers’ virtual experiences and affect their intentions to purchase products. SOR indicates online environmental stimuli that influence customers’ internal states and their response behaviors. Guided by the SOR model, this study identifies the influences of social commerce components (stimulus, S) (i.e., ratings, reviews, recommendations, and referrals) on social interactions (organism, O) (i.e., social support, social presence,

closeness, and familiarity) and trust (O) (trust in product recommendations), which then have an effect on social shopping intention (response, R). The results provide valuable information for academics and practitioners who support social commerce strategies.

## THEORETICAL BACKGROUND

### *The stimulus–organism–response (SOR) model*

The SOR model of environmental psychology suggests that various aspects of the environment (S), such as physical and nonphysical elements of a store, can affect peoples' internal states or organismic experiences (O), such as perceptual, physiological, feeling, and thinking activities, which in turn drive their behavioral responses (R), such as satisfaction, patronage, intention, number of items purchased, and amount of money spent in the store (Mehrabian and Russell, 1974). Several researchers have demonstrated the effects that retail and website design features exert on customers' behaviors, arguing that the retail environment plays a crucial part in generating cognitive and emotional evaluations leading to behavioral responses (Kumar and Kim, 2014; Bitner, 1992; Baker *et al.*, 1994). Previous studies have extensively applied the SOR model to explore online customers' behaviors. For example, Animesh *et al.* (2011) adapted the SOR model to the virtual world and conceptualized stimuli as environmental cues that are relevant to technological (interactivity and sociability) and spatial (density and stability) environments.

In the context of the SOR model applied to online shopping, stimuli (S) are social commerce components that affect the internal states of the customer. According to Hajli (2013) and Shadkam and O'Hara (2013), social commerce constructs are website features that connect customers and enable them to discover, share, recommend, rate, and purchase products. A set of functions or features added onto e-commerce websites can be used to improve sociability (Hajli *et al.*, 2015). Examples of features that support these social shopping activities include wish lists, discussion forums, product reviews, videos, blogs, podcasts, tagging, social networks, ranking tools, and recommendation systems (Ng, 2013; Kim and Park, 2013; Shadkam and O'Hara, 2013). The present study adopts ratings, reviews, recommendations, and referrals as social commerce constructs that represent features provided by social commerce sites. Hajli (2015) treated social commerce constructs as second-order latent constructs that encompass two subconstructs with a positive correlation between them: ratings and reviews correlated with recommendations and referrals. Ratings and reviews are defined as the toolset provided by social commerce sites that enables customers to exchange product feedback and inform each other's choices (Shadkam and O'Hara, 2013). Recommendations and referrals are online activities that enable customers to exchange information, thus assisting their peers in making purchasing decisions (Kim and Park, 2013). Ratings and reviews, which are generally visible to all, differ from recommendations and referrals, which are personalized social media endorsements for goods and services designed to realize the referral value of customers (Shadkam and O'Hara, 2013). Social commerce constructs are stimuli that online vendors can use to influence customers' affective and cognitive evaluations.

Organism (O) refers to the internal processes and structures intervening between stimuli that are external to the person and the final actions, reactions, and or responses emitted, "which consist of perceptual, physiological, feeling, and thinking activities" (Bagozzi, 1986). This study adopts two notions, namely social interactions and trust, to represent customers' internal processes. A social interaction is defined as a link or tie established via reciprocity behavior between two actors (Wang and Chiang, 2009). Several previous studies (e.g., Wang & Zhang, (2012); Shin, (2013); Zhang *et al.*, (2014) reported that social commerce uses social media to support social interactions and user contributions. Research related to social interactions and social processes can assist online vendors in understanding customers' behaviors and predicting outcomes (Liang and Turban, 2011/2012). Therefore, this study regards social interactions as processes internal to customers (O).

Researchers have identified two types of environmentally induced internal evaluation: cognitive and affective states (Ward *et al.*, 1992). Cognitive states are associated with information-processing and inference theories, whereas affective states are related to emotions (Kumar and Kim, 2014). This study uses social presence and social support to represent cognitive states, whereas closeness and familiarity are used to identify affective states. Social presence is defined as the degree to which a customer is perceived as a "real person" in mediated communication (Park and Cameron, 2014). The definitions imply that a social medium enables a customer to experience another person as being psychologically present. Social presence reflects a customer's social interactions with others through comments, product reviews, and social media linkages (Klaus, 2013). The lack of social presence may impede the growth of e-commerce because of insufficient human interaction (Gefen and Straub, 2003). Social support refers to people's perceptions of being cared for, responded to, and helped by others in their social group (Liang *et al.*, 2011/2012). Social support is typified by the social interactions of people in a group where they are answered and supported (Hajli, 2014). Customer interactions include social values and thus provide a functional equivalent of social support (Kang and Ridgway, 1996; Zhang *et al.*, 2014). Following Hajli (2014), the present study adopted informational and emotional support to represent social support.

Closeness is defined as a feeling of intimacy and emotional bonding that involves intense liking, moral support from friends on social networking sites, and the ability to tolerate other friends' flaws (Lee and Kwon, 2011). Familiarity refers to customers' feelings of understanding between social network friends, often based on previous interactions, experiences, and learning the why, who, and when of what others do (Lee and Kwon, 2011). Some research has shown that closeness and familiarity can be used to present social interactions. For example, Ng (2013) investigated the influences of closeness and familiarity on intention to purchase in social commerce environments. Gobbini *et al.* (2004) suggested that familiarity accrues naturally with years of social interaction. Lowenthal and Haven (1968) regarded intimacy as a critical variable for interaction and adaptation. Although Gefen (2000) identified familiarity as a cognitive state and defined it as people's understanding of an entity, the present study follows Lee and Kwon (2011) and defines familiarity as an emotion. Specifically, this study investigates how a customer feels a familiarity with friends within social commerce sites and how the feelings pertain to personal experience. Familiarity can be regarded as an affective state instead of as a cognitive evaluation. In addition, Ng (2013) and Lee and Kwon (2011) confirmed

that closeness and familiarity are affective factors created cumulatively over time. Therefore, closeness and familiarity are employed to identify affective states of social interactions. Because of the characteristics of social networking sites, this study proposes that the social commerce environment should enable customers to form interpersonal connections and social interactions with others through social support, social presence, closeness, and familiarity.

Only customers who trust an online vendor to refrain from misuse of information purchase products from that online vendor. Trust can be transferred from one source to another. Mutz (2005) argued that trust reduces transaction costs so that customers do not need to monitor sellers' or other parties' activities. Hsiao et al. (2010) and Ng (2013) confirmed that trust is expected to be transferable to other related sources. For example, customers may first trust a website and then trust products recommended by that website. Kim and Park (2013) argued that no study has investigated how the formation of trust facilitates trust performance. This study explores the transfer of trust from social network members to product recommendations.

Response (R) is associated with customers' behavioral reactions. In the context of online shopping, response to stimuli is often termed a "behavioral intention." Website characteristics have been found to influence behavioral intention indirectly through cognitive and affective evaluations (Zhang *et al.*, 2014). Purchase intention is defined as the likelihood of a consumer to purchase a service or product in the future (Richardson *et al.*, 1996). Because actual behavior is difficult to measure, the present study adopts the argument of Venkatesh and Davis (2000), which states that behavioral intention is a valid predictor for actual behavior. Purchase intention can be used to anticipate a customer's possible actions (Hajli, 2014). Therefore, this study's research model uses social shopping intention as the response to describe customers' intentions to buy products on social commerce sites.

## **HYPOTHESES DEVELOPMENT**

### *Social commerce components and cognitive states of social interactions*

When social commerce sites provide ratings and reviews written by the general public, customers regard these amateur reviews as more credible and useful information because this information comes from their peers rather than from paid professionals. Peer-written ratings and reviews enhance social interaction and thus enhance customers' perceptions of those social commerce sites. The more frequently customers observe interpersonal interactions in an online context, the more their perceptions of social presence increase (Park and Cameron, 2014). Recommendations and referrals assist customers in receiving and making recommendations on what to buy, read, eat, and do. Recommendations and referrals improve online shopping experiences and assist shoppers in making decisions (Shen, 2012). Browsing and collecting personal experiences facilitate social interactions and thus increase social presence. Hassanein and Head (2007) observed that a Web interface's imaginary interaction elements and design elements can manipulate online customers' perceptions of social presence. Therefore, ratings and reviews as well as recommendations and referrals posted on social commerce sites enable customers to experience others as being psychologically present, thus increasing their perceptions of social presence. Thus,

H<sub>1</sub>. Customers' ratings and reviews and their recommendations and referrals on social commerce websites exert a positive influence on their perceptions of social presence.

On social commerce sites, customers share information regarding products and services with friends. Liang et al. (2011/2012) determined that online shoppers obtain social support from social commerce sites. Through ratings and reviews as well as recommendations and referrals, customers can interact with others to exchange content, self-disclosures, and personal experiences. Social commerce constructs that apply social and website technologies provide social support to customers and provide customers opportunities to communicate, rate products, review others' opinions, share their experiences, and recommend products and services (Hajli, 2013). Receiving and reviewing information provided by other customers might assist shoppers in solving their problems and thus provide them with social support. Zhang et al. (2014) proposed that, by interacting with others in a social commerce environment, customers may present themselves socially and provide social support to others. Therefore, through ratings and reviews as well as recommendations and referrals posted on social commerce sites, customers can interact with and exchange information with others, leading to feelings of receiving care, love, and support from friends.

H<sub>2</sub>. Customers' ratings and reviews and their recommendations and referrals on social commerce websites exert positive influences on perceptions of social support, including informational and emotional support.

### *Social commerce components and affective states of social interactions*

Familiarity is a sense of understanding that is often based on previous interactions (Gefen, 2000). The social features of social commerce sites offer unique and interesting capabilities for online shopping (Gonçalves Curty and Zhang, 2013). On social commerce sites that have rating and review functions, customers use these functions to express their personal experiences. Customers can accept recommendations or referrals from friends to assist them in purchasing decisions; social commerce sites provide platforms on which customers receive feedback and share information with each other. Park and Cameron (2014) determined that human voice and feedback mechanisms positively enhance perceived interactivity. Sprecher et al. (2012) suggested that receiving disclosure information from others reduces uncertainty and increases a sense of familiarity with them. Collectively, rating and reviewing as well as recommendation and referrals are services provided by social commerce sites to enhance a sense of familiarity in social interactions among customers. Thus,

H<sub>3</sub>. Customers' ratings and reviews and their recommendations and referrals on social commerce websites exert positive influences on feelings of familiarity.

Social networking sites provide a space where people have opportunities to participate with others in actively exchanging and transferring information. Intense interaction among participants allows relationships to be built (Huang and Benyoucef, 2013). In other words, social networking sites enable users to connect to social networks and develop and maintain relationships with others (Lin and Lu, 2011). Liang et al. (2011/2012) proposed that online communities can deliver social value to their users because

people can build close relationships with others. Hajli (2013) argued that reviews from friends add an emotional, personal touch to the decision-making process of buying. Therefore, through ratings and reviews, forums and communities, and recommendations and referrals, customers have opportunities to develop relationships with others, leading to feelings of closeness with friends.

H<sub>4</sub>. Customers' ratings and reviews and their recommendations and referrals on social commerce websites exert positive influences on feelings of closeness.

#### *Cognitive state and affective states of social interactions*

In an online environment with a high level of social presence, users tend to stay in contact with people they know, to discuss things with others (Kang and Johnson, 2013). In particular, Park and Cameron (2014) proposed that levels of social presence increase as interpersonal interactions are perceived in an online context. If customers experience a website as high in social presence, customers experience other humans as being psychologically present. Customers feel social appeal and human warmth, just as they feel these feelings during face-to-face shopping experiences (Shen, 2012). These experiences with warmth and pleasure motivate customers to engage in repeated interactions. According to Lee and Kwon (2011), familiarity occurs through the quantity of prior interactions and repeated interactions. Collectively, social presence leads to a feeling of familiarity. Thus, H<sub>5</sub>. The perceptions of social presence are positively related to a feeling of familiarity.

Through social interactions on social commerce sites, customers build their online identities and form networks to obtain social benefits such as social support (Zhang *et al.*, 2014). According to social exchange theory (Blau, 1964), when individuals obtain benefits from others, they tend to reciprocate by giving to others. People receiving support tend to develop relationships with friends in their communities (Wellman and Wortley, 1990). A social networking site is a platform on which users exchange support with one another (Liang *et al.*, 2011/2012). A community with good social support motivates people to interact with each other for mutual help (Laurenceau *et al.*, 1998). During social interactions, customers' social desires for belonging are satisfied, and customers feel that they are cared for, valued, and helped by others. The inherent human tendency of reciprocity causes customers to endeavor to care for and help others. Reciprocity enables customers to understand each other and increases the frequency of interactions. In particular, familiarity occurs through repeated interactions (Lee and Kwon, 2011). Therefore, customers perceiving high levels of social support tend to have higher levels of familiarity with others on social commerce sites. Thus,

H<sub>6</sub>. Perceptions of social support, including informational and emotional support, are positively related to a feeling of familiarity.

#### *Cognitive states of social interactions and trust*

Xu-Priour *et al.* (2014) argued that social interaction is positively related to trust perception. Customers feel more secure in an online shopping environment with social presence and social applications than in an online environment without such things (Hajli, 2012). Experiencing social interactions enhances users' trust in their personal relationships. Hassanein and Head (2007) determined that higher levels of perceived social presence generate greater trust in online shopping websites. Zhang *et al.* (2014) maintained that, in situations with low social presence, customers feel that it may be easier to engage in untrustworthy behavior. Therefore, constructing an online environment with social presence is conducive to trust formation (Ou *et al.*, 2014). Social commerce sites with high social presence tend to attract customers who interact with others by means such as online ratings, recommendations, and votes. Social networking sites that enable customers to join and offer positive support to other users provide customers opportunities to gain knowledge. Reciprocity motivates customers who experience good social support to share valuable shopping information or common perspectives with others (Zhang *et al.*, 2014). These frequent social interactions build trust relationships and increase sales (Wang and Chiang, 2009; Hajli, 2013). In addition, strong social support causes users to feel connected with friends on social networking sites, leading the users to trust those friends (Liang *et al.*, 2011/2012). The availability of social support, including informational and emotional support, leads to customers offering committed trust and satisfaction to the network (Hajli, 2014). Therefore, social support is related to trust beliefs. Receiving social support from other members on a social networking sites leads to greater trust in other members' product recommendations. Thus, the following two hypotheses are proposed:

H<sub>7</sub>. Perceptions of social presence are positively related to trust in product recommendations.

H<sub>8</sub>. Perceptions of social support, including informational and emotional support, are positively related to trust in product recommendations.

#### *Affective state of social interactions and trust*

Social commerce sites are platforms that allow customers to participate in social interactions. Human beings inherently prefer a warm and social environment. Social interaction exists in terms of empathy and intimacy between friends during the process of information sharing and receiving (Amblee and Bu, 2011/2012). Specifically, customers have opportunities to become acquainted and familiar with other members as they interact, which fosters improved communication. Through intense interaction with friends on social commerce sites, customers feel understood, cared for, and validated; close relationships develop from these feelings. Lee and Kwon (2011) argued that familiarity is a prerequisite of intimacy. Hinds and Cramton (2013) proposed that familiarity increases attraction, which in turn increases closeness. Thus, when customers are aware of others on social commerce sites, they feel that they belong to the community and tend to feel closeness with other users.

H<sub>9</sub>. A feeling of familiarity is positively related to the feeling of closeness.

Familiarity is a subjective mechanism that leads to trust (Gefen, 2000; Das *et al.*, 2003). Through strong and symmetrical social interactions with other members, customers foster a sense of belonging and increased trust in other members, which leads to

trusting relationships (Ng, 2013; Wang and Chiang, 2009). Familiarity can reduce uncertainty and simplify relationships so that a customer may increase the confidence that they place in a particular website (Flavián and Guinalú, 2007). Therefore, when customers feel familiarity with members of a social network, they tend to trust product recommendations from within that social network.

When customers feel closeness with others, they tend to spend time together, tolerate friends' mistakes, and develop deep relationships (Marsden and Campbell, 1984). The relationships among individuals on social networking sites contribute trust to the network (Hajli, 2014). Customers on social networking sites are encouraged to interact with others. Social interactions enhance feelings of closeness and thus decrease social distance. Mutz (2009) proposed that, as social distance declines, trust increases. In other words, when customers feel close to people in a social network, they tend to trust product recommendations from the members of that social network. Thus,

H<sub>10</sub>. A feeling of familiarity is positively related to trust in product recommendations.

H<sub>11</sub>. A feeling of closeness is positively related to trust in product recommendations.

#### *Trust and social shopping intention*

A high level of social trust reduces transaction costs and facilitates exchange processes between customers (Hajli, 2013). Trust reduces uncertainty in online purchasing and thus enables complex decisions (Weisberg *et al.*, 2011). When people think their exchange partners are trustworthy, they like to engage in economic transactions with each other (Mutz, 2009). Several previous studies, such as Kang & Johnson, (2013), and Xu-Priour *et al.*, (2014) have confirmed the significant effect of trust on customers' intentions to purchase from websites or on their loyalty to particular websites. Hsiao *et al.* (2010) determined that trust in product recommendations influences customers' purchase intentions. Accordingly, when customers trust product recommendations on social commerce sites, their intentions to purchase the recommended product are stimulated.

H<sub>12</sub> Trust in a product recommendation is positively related to social shopping intention.

## **METHODOLOGY**

### *Measurement development*

A questionnaire was developed for the survey used in this study. A scale purification process was conducted according to Churchill (1979). To assess social commerce construct, this study uses seven items adapted from Pagani and Mirab (2011/2012). For social presence, four items were adopted from Animesh *et al.* (2011). Regarding social support, this study uses six items adapted from (2011/2012). Familiarity and closeness were measured by six items adapted from Ng (2013). Trust in product recommendation and social shopping intention were measured by six items adapted from Hsiao *et al.* (2010). All measurement items were measured using a 7-point Likert scale ranging from 1 (strongly disagree) to 7 (strongly agree).

### *Survey administration*

Because this study investigated the influence of characteristics of social commerce sites on customers' virtual experiences and thus on their intentions to purchase products, the unit of analysis was the individual customer of one social commerce site: Kidshome. In addition to transaction mechanisms, Kidshome also provides communication and interaction functions, including information sharing and commenting. By the end of 2015, more than 42,000 customers registered as members on Kidshome. Most products sold on Kidshome are related to education and parenting. Parents, particularly parents with newborns, require abundant information on nurturing their children. On Kidshome, customers can ask questions or post their comments regarding their experiences with purchased products. Specifically, Kidshome provides a platform, which includes ratings and reviews as well as recommendations and referrals, on which experienced parents can share information and inexperienced parents can acquire information.

A Web-based questionnaire was used to collect representative samples for this study. Data were collected between November and December 2015. To invite people with social shopping experience on Kidshome to participate in the survey, a banner with a hyperlink to our Web survey was published on the Facebook fan page of Kidshome. Only respondents that had conducted at least one transaction on Kidshome in the previous 3 months were selected. In total, 420 customers participated in this study. Twelve responses were invalid, leaving 408 usable questionnaires. In the sample, 66% of the respondents were women, and nearly 68% of the respondents had completed a university education. Approximately 51% of the respondents were between 20 and 34 years old. More than 55% had more than 3 years of social shopping experience, and approximately 65% reported spending an average of US\$15–25 each time that they purchased an item on Kidshome. The characteristics of our sample mostly corresponded with the shopper demographics of Kidshome, on which 65% of the online shoppers are women and over 70% are less than 40 years old.

Multiple tests were conducted to determine the validity of the survey data. To test for nonresponse bias, this study compared the responses of early- and late-returned surveys (Armstrong and Overton, 1977). The *t*-test results showed that the response differences were nonsignificant (confidence interval, 99%). To detect common method bias, an analysis proposed by Harman (1967) was used. The results demonstrated that a single factor did not emerge and that the first factor did not account for most of variance, indicating that common method bias was unlikely to be a severe concern.

## **RESEARCH RESULTS**

### *Assessment of the measurement model*

This study determined the reliability and validity of all constructs and conducted exploratory factor analyses to ensure high loadings on hypothesized factors and low loadings on crossloadings in data sets. All the items loaded onto the expected factors were without significant crossloading. The Cronbach's alpha of each multiitem variable was over 0.6, demonstrating high internal consistency for each variable. According to Bagozzi and Yi (1988), composite reliability (CR) scores were used to assess construct reliability, whereas averaged variance extracted (AVE) was employed to ensure convergent validity. As shown in Table

1, all factors exhibited CRs above 0.7, and the AVE values satisfactorily exceeded 0.5. Finally, discriminant validity was assessed using Fornell and Larcker's (1981) recommended procedure. Table 2 shows that the square root of the AVEs was greater than all of the interconstruct correlations, indicating sufficient discriminant validity.

Table 1 Factor Loadings and Reliability

Construct/indicators	Loading	T-statistics	CR <sup>1</sup>	AVE <sup>2</sup>	Cronbach's $\alpha$
<i>Social commerce construct</i>					
Rating and reviews			0.94	0.84	0.91
SC1	0.90	69.00			
SC2	0.93	95.95			
SC3	0.93	100.09			
Recommendation and referrals			0.94	0.79	0.91
SC4	0.85	49.67			
SC5	0.91	88.38			
SC6	0.90	71.25			
SC7	0.89	58.88			
<i>Social presence</i>					
SP1	0.86	40.65	0.93	0.76	0.89
SP2	0.89	65.57			
SP3	0.86	52.64			
SP4	0.88	67.24			
<i>Informational support</i>					
IS1	0.91	48.75	0.94	0.84	0.91
IS2	0.94	98.69			
IS3	0.91	86.68			
<i>Emotional support</i>					
ES1	0.89	57.19	0.93	0.81	0.88
ES2	0.91	78.22			
ES3	0.89	73.20			
<i>Familiarity</i>					
FA1	0.93	89.58	0.90	0.75	0.83
FA2	0.91	60.24			
FA3	0.76	18.82			
<i>Closeness</i>					
CL1	0.87	50.50	0.88	0.72	0.80
CL2	0.88	59.65			
CL3	0.78	26.07			
<i>Trust in product recommendation</i>					
TR1	0.94	98.45	0.94	0.84	0.90
TR2	0.95	130.38			
TR3	0.86	35.50			
<i>Social shopping intention</i>					
SI1	0.91	65.08	0.93	0.82	0.89
SI2	0.94	108.60			
SI3	0.87	50.85			

Note: <sup>1</sup> CR, composite reliability; <sup>2</sup>AVE, average variance extracted, both are not applicable to formative scale.

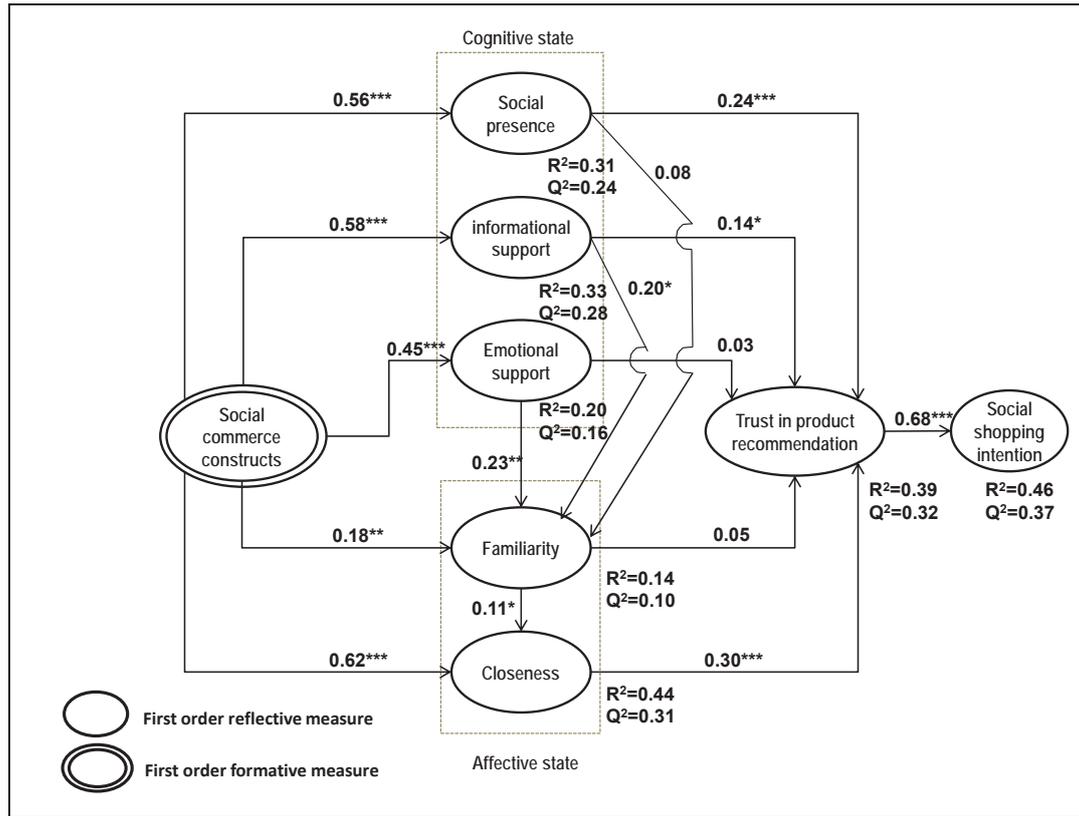
Testing the hypotheses

Figure 1 presents the estimates of the partial least squares analysis. Bootstrapping was employed with 5000 subsamples to assess the significance of the indicators and path coefficients. The research model explained a considerable degree of the variance for the endogenous variables, with a mean global R<sup>2</sup> of 0.32. The nonparametric Stone–Geisser test revealed positive values for social presence (0.24), informational support (0.28), emotional support (0.16), familiarity (0.10), closeness (0.31), trust in product recommendations (0.32), and behavioral intention (0.37), which signify the successful prediction and predictive relevance of the model.

Table 2 Correlations among Major Constructs

Variable	(a)	(b)	(c)	(d)	(e)	(f)	(g)	(h)	(i)
Rating and reviews	<b>0.95</b>								
Recommendation and referrals	0.62	<b>0.95</b>							
Social presence	0.44	0.55	<b>0.94</b>						
Informational support	0.50	0.54	0.55	<b>0.95</b>					
Emotional support	0.42	0.39	0.44	0.67	<b>0.94</b>				
Familiarity	0.22	0.35	0.27	0.32	0.21	<b>0.91</b>			
Closeness	0.64	0.55	0.57	0.63	0.51	0.31	<b>0.89</b>		
Trust in product recommendation	0.57	0.69	0.52	0.50	0.40	0.26	0.56	<b>0.95</b>	
Social shopping intention	0.36	0.49	0.37	0.39	0.37	0.19	0.41	0.68	<b>0.94</b>
Mean	3.86	4.38	4.51	4.55	4.44	4.38	4.11	4.10	4.35

Note: <sup>1</sup> Diagonal elements are the square root of average variance extracted (AVE) of the reflective scales.  
<sup>2</sup> Off-diagonal elements are correlations between construct.



Note: \*p<0.05, \*\*p<0.01 \*\*\*p<0.001

Figure 1 PLS Results for the Proposed Model

Figure 1 shows that social commerce constructs exerted a positive and significant effect on social presence ( $\beta = 0.56, p < .001$ ), informational support ( $\beta = 0.58, p < .001$ ), emotional support ( $\beta = 0.45, p < .001$ ), familiarity ( $\beta = 0.18, p < .01$ ), and closeness ( $\beta = 0.62, p < .001$ ). Therefore, H<sub>1</sub>, H<sub>2</sub>, H<sub>3</sub>, and H<sub>4</sub> were supported. Social presence ( $\beta = 0.24, p < .001$ ) and informational support ( $\beta = 0.14, p < .05$ ) had an effect on intention to trust product recommendations, but emotional support ( $\beta = 0.03, p > .05$ ) did not have an effect on trust in product recommendations. Emotional support ( $\beta = 0.23, p < .01$ ) and informational support ( $\beta = 0.20, p < .05$ ) exerted significant effects on familiarity, but social presence ( $\beta = 0.08, p > .05$ ) did not have a significant influence on familiarity. Thus, H<sub>5</sub> was not supported; H<sub>6</sub> and H<sub>7</sub> were supported; and H<sub>8</sub> was partially supported. Furthermore, closeness exerted a positive and significant effect on trust in product recommendations ( $\beta = 0.30, p < .001$ ). Familiarity exerted a positive and significant effect on closeness ( $\beta = 0.11, p < .05$ ) but did not exert a significant effect on trust in product recommendations ( $\beta = 0.05, p > .05$ ). Finally, trust in product recommendations exerted a significant effect on social shopping intentions ( $\beta = 0.68, p < .001$ ). Accordingly, H<sub>9</sub>, H<sub>11</sub>, and H<sub>12</sub> were supported, but H<sub>10</sub> was not supported.

## RESEARCH SUGGESTIONS AND IMPLICATIONS

### Research findings

Several findings can be derived from this study. First, ratings and reviews as well as recommendations and referrals posted on social commerce sites increase customers' perceptions of social presence and social support. These findings are consistent with those of several previous studies. Hassanein and Head (2007) suggested that design elements of Web interfaces manipulate online customer perceptions of social presence. Shadkam and O'Hara (2013) argued that some functions in social commerce sites shaped interactive areas where people offered each other support. Through social commerce constructs, including ratings and reviews as well as recommendations and referrals, customers can develop familiarity and relationships with other customers on social commerce sites. This finding is consistent with Animesh et al. (2011) and Sprecher et al. (2012). They suggested that increased social interactions reduce uncertainty and increase familiarity, affection, belongingness, and intimacy with others. When customers share and receive information on social commerce sites, customers feel understood and cared for; they then develop close relationships with online friends.

Second, when customers are aware of others on social commerce sites, they tend to trust other members' product recommendations. This result is consistent with those of previous studies, which reported that situations with high social presence are conducive to trustworthy behavior (Klaus, 2013; Zhang et al., 2014). However, social presence does not exert an influence on familiarity. Specifically, customers with an awareness of others on social commerce sites do not feel familiarity with others on those social commerce sites. This phenomenon is attributable to the rapid growth of technological development. Social presence represents the extent to which a medium allows a user to experience others as being psychologically present (Shen, 2012). Social media sites that are interactive and able to transmit diverse information have high social presence (Weisberg et al., 2011). With

increased bandwidth, advanced design technologies such as 3D and visual effects can make websites increasingly user-friendly. As shown in Table 2, the mean score for familiarity is 4.81, which is higher than those for other constructs. Specifically, social commerce sites that provide high social presence seem to be a necessity; customers require social presence to browse the sites easily without requiring a manual. Customers who choose to purchase products from social commerce sites are skilled at using social networking sites and thus may not be bothered by website interfaces. Thus, websites that are high or low in social presence may not influence customers' feelings regarding their familiarity with other users on the social commerce sites.

Third, customers perceiving high levels of informational and emotional support tend to have more familiarity with others on social commerce sites. This result is consistent with previous studies. For example, Liang et al. (2011/2012) determined that sharing supportive information enhances friendship and trust among members. Social support motivates people to interact with others, offering mutual help, and causes customers to feel connected with friends, leading to familiarity (Laurenceau *et al.*, 1998; Lee and Kwon, 2011). Furthermore, informational social support is positively related to trust in other members' product recommendations. According to Hajli (2013), social support reduces perceived risk and thus increases the level of trust. Customers perceiving high levels of informational support tend to trust other members' product recommendations on social commerce sites. However, emotional support does not affect customers' trust in other members' product recommendations. This finding seems counterintuitive compared with the conventional wisdom, which holds that the availability of social support leads to committed trust in the network. One possible explanation might be that social trust is closely related to transaction costs in business interactions (Mutz, 2005). Social support is a multidimensional construct (Liang *et al.*, 2011/2012). Emotional support contributes to the feeling that one is loved or a member of the group (Bai *et al.*, 2015). In fact, emotional support enables customers to confide in and rely on another person because they perceive themselves as being cared for or empathized with (Hajli, 2015). However, emotional support does not reduce customers' transaction costs on social commerce sites. Therefore, customers who acquire emotional support from other members may not increase their trust in their product recommendations.

Fourth, when customers are aware of others on social commerce sites, they feel close to others. The finding agrees with Hinds and Cramton (2013), who suggested that familiarity facilitates attraction and further enhances closeness. The finding also agrees with the claim of Linke (2012) that social familiarity leads to greater social closeness. However, this study did not find that familiarity facilitates trust, as demonstrated by Flavián et al. (2007). Specifically, although customers feel familiar with social network members, they may not trust products recommended by those social network members. This variation in results is attributable to the difference in research context. Previous studies examining the influence of familiarity on trust mainly focused on familiarity between users and services on websites (Gefen, 2000; Lee and Kwon, 2011), the Internet (Flavián and Guinalíu, 2007), or systems (Komiak and Benbasat, 2006); however, this study explains the familiarity between customers on social commerce sites. Interactions between systems and machines are different from those between users. The familiarity that a customer feels toward a system is a specific activity-based cognizance founded on previous experience or the knowledge of how to use a particular interface (Gefen, 2000), whereas the familiarity that a customer feels toward a human references knowledge about that person (Mashek *et al.*, 2003). Specifically, familiarity with a system results from repeated usage; ease of use and usefulness can be appreciated, and thus trust can be formed. If users cannot see the benefits of using a system, they may never use the system enough to become familiar with it. With human interaction, customers may be familiar with a person, but they may not trust that person. For example, customers may be familiar with people who typically post prejudiced information on certain social commerce sites; although a certain familiarity has developed, the customers may not trust those people because they consider the posted information to be biased.

Fifth, when customers feel close with other members on social commerce sites, they tend to trust their product recommendations and to have higher levels of social shopping intention. This finding is consistent with Mutz (2009), who argued that feelings of closeness decrease social distance and increase trust. Hsiao et al. (2010) determined that trust in product recommendations influences customers' purchase intentions. Accordingly, when customers feel some closeness with other members on social commerce sites, fears of risk regarding product recommendations decrease, and thus customer intentions to purchase the recommended product are stimulated.

### *Theoretical implications*

This study differs from previous studies in that it makes three critical contributions. Although social commerce has evolved from e-commerce, it shifts the online shopping environment from a business orientation to a user orientation and should be distinguished from the concept of e-commerce (Yadav *et al.*, 2013). Some studies have utilized behavioral theories or models to explore customers' social commerce intentions, such as the technology acceptance model (Shen, 2012; Shin, 2013), the unified theory of user acceptance and use of technology (Yang and Forney, 2013; Gatautis and Medziausiene, 2014), and the Engel, Kollat, and Blackwell model (Kang and Johnson, 2013; Park and Cho, 2012). However, few studies have provided a comprehensive framework for discussing the components of social commerce sites and how customers react to these social commerce features. The understanding of social commerce is scattered, limited, and biased at time by certain perspectives (Wang and Zhang, 2012). The first critical contribution of this study is that, by applying the SOR model (Mehrabian and Russell, 1974), it verified the effects of social commerce components (S) (i.e., ratings and reviews as well as recommendations and referrals) on social interactions (O) (i.e., social support, social presence, closeness, and familiarity) and trust (O) (trust in product recommendations), which ultimately exerts an effect on purchase intention (R). The present research responds to Huang and Benyoucef's (2015) suggestion that "users are finding the traditional way of shopping online to be no longer sufficient or satisfying" (p. 2).

Social commerce realizes the potential massive buying power of online social groups and forces Web-based companies to implement and launch social commerce features to enhance social interaction and collaboration among customers. These social features strengthen business relationships with customers and increase traffic to company websites for increased profits. Design in traditional e-commerce is catalog-based, whereas design in social commerce combines virtual markets with social venues for

cooperation (Wang and Zhang, 2012). However, previous studies considered social features only as isolated design elements, and no significant research has been dedicated to designing social commerce platforms (Huang and Benyoucef, 2013). Few studies have investigated the effects of design components on the social and relational perspectives of online shopping (Kim *et al.*, 2013). This study followed Hajli (2015) and investigated the influences of social commerce constructs, in terms of ratings and reviews as well as recommendation and referrals, on customers' social interactions and trust, in response to the statement by Animesh *et al.* (2011) that "the social dimension of virtual worlds and the environmental features that affect it are likely to influence the purchasing intentions of individuals" (p. 790). In addition, this study responds to Shin's (2013) suggestion that "it is clear that social commerce needs to focus on user-centered design in order to become a mainstream phenomenon" (p. 54). The second critical contribution of this study is that it proves that developing websites with socially rich features assists online vendors in attracting customers and accommodating their needs.

Social commerce uses social media to support social interaction and user contributions. However, little is known about how interactions take place in online social environments (Yadav *et al.*, 2013). An individual is not able to have an emotional reaction to a stimulus in the absence of some sort of cognitive appraisal of the stimulus (Kumar and Kim, 2014). This study investigates the effects of cognitive state (social presence and social support) and affective state of social interactions (closeness and familiarity) on trust. The findings of this study are consistent with Bagozzi (1986), who stated that intervening processes and structures consist of perceptual, physiological, feeling, and thinking activities. This study reflects the recommendation of Shin (2013), who stated that "it is not clear whether marketers really understand customer feelings about social commerce, and how they interact within sites" (p. 53). This study involved developing a comprehensive research framework to enable supporting website design features in social commerce for social shoppers. The third critical contribution of this study is that the present findings explain why customers decide to purchase products from social commerce sites and how "like" turns into "buy."

### *Managerial implications*

This study provides relevant insights for managing social commerce sites. First, social commerce is user-oriented, whereas traditional e-commerce is product-oriented (Bai *et al.*, 2015). The results suggest that social commerce constructs, including ratings and reviews as well as recommendations and referrals, facilitate cognitive and affective states of social interaction. These social features strengthen business relationships with customers and increase profitable traffic to company websites (Gonçalves Curty and Zhang, 2013). With the aid of social commerce constructs, customers perceive high levels of social presence and social support and feel familiarity and closeness with other members. More importantly, social media sites not only facilitate online communication but also offer commercial value by supporting customer interaction. Managers of online vendors should also encourage and empower customers to be active content generators so that firms can increase profits by attracting potential buyers. Second, the feeling of closeness with other members on social commerce sites (0.30) had the greatest impact on trust of product recommendations, followed by social presence (0.24) and information support (0.15). Closeness enables users to feel secure and can strengthen and improve relationships between parties (Lee and Kwon, 2011). Instead of directly pushing product information toward users, online vendors should appropriately guide users to understand the product through interactions with other customers. Social presence has a direct impact on trust in product recommendations. The degree of social presence is determined by a medium that allows customers to establish connections with others (Animesh *et al.*, 2011). Hence, online vendors should apply diverse and advanced technologies, including QR codes and mobile apps, to create social interactions. Furthermore, information support can have a direct influence on trust of product recommendations (0.14) or an indirect effect through familiarity and closeness ( $0.2 \times 0.11 \times 0.3 = 0.01$ ). In the online environment, informational support provides solutions, plans, or interpretations (Liang *et al.*, 2011/2012). According to transaction cost theory (Williamson, 1981), firms pursue profit maximization, which requires cost minimization. Liang and Huang (1998) confirmed that transaction cost theory is a viable theory in electronic commerce for explaining acquisition decisions, in that people prefer to conduct transactions in the most economical way. Insufficient information about alternative suppliers can be a transaction cost for a consumer. Similarly, insufficient information about a customer's credit and reputation can generate transaction costs for a vendor. Following the logic of transaction cost theory, information support assists others in solving this problem, thus reducing transaction costs. Therefore, information provided only by online vendors is not sufficient, and online vendors should facilitate social interactions by encouraging information sharing.

Third, emotional support and familiarity do not have direct impacts on trust of product recommendations. However, emotional support and familiarity remain crucial because both of them have indirect effects on trust of product recommendations through closeness. Emotional support facilitates a feeling of familiarity, which in turn triggers a feeling of closeness and further enhances trust in other members' product recommendations. According to the SOR model, cognitive and emotional organism states may influence customers' responses to environmental stimuli (Zhang *et al.*, 2014). Similar to Huang and Benyoucef (2015), who suggested that social aspects and website quality are crucial for social commerce sites, this study affirms that both the cognitive and emotional states of social interactions should be fully considered. Although online vendors cannot control the perceptions and feelings of customers using their websites, the social features of social commerce sites provide unique capabilities for customers. For example, the website should be user-friendly and secure so that customers can notice when they receive support from other members.

### *Research limitations and directions for further study*

This study has several limitations. First, this study used self-report measures in which customers were asked to recall their experiences on one specific social commerce site over the preceding 3 months. Future research aimed at replication should examine the model using different types of social commerce site (e.g., online group buying). Second, this study was conducted in Taiwan. Future research may include a cross-cultural component to enhance the generalizability of the results. Third, this study uses cross-sectional data. Future researchers can collect data longitudinally to determine changes over time.

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# Sectioning Social Capital in Virtual World Platforms

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## ABSTRACT

Virtual world platforms is developed and advanced, which provides a suitable platform for users to interaction, communicate, and build social relationships supported with social capital. Social capital in form of bridging and bonding are likely influences by the nature of the virtual world platforms. This study examine the association of the two forms of social capital within social, gaming, and mixed virtual world platforms. ANOVA is employed to analyses data collected from Second Life, Word of Warcraft, and Entropia Universe users through the online survey. Findings reveal that there is no significant differences in bridging social capital between the different virtual word platforms. However, there is a significant difference in bonding social capital between the different virtual world platforms. The finding of this study helps developers and business' build a stronger social capital relationships with their clients, which in-turn increases the loyalty and trust between users and developers and/or business'.

## KEYWORDS

Social capital, virtual world platform, bridging and bonding

## INTRODUCTION

In recent years social media networks (SMNs), virtual worlds (VWs), and virtual reality (V-reality), and their influence on developing social capital have gained great research interest in the academic field (Huvila *et al.*, 2010; Huvila, Ek and Widén, 2014; Reer and Krämer, 2014; Zhang and Kaufman, 2015) and published in a number of management, business, information systems, and information technology journals.

As with the rapid development and improvement of the VW platforms, social capital development could differ in so many different context based on the nature of the investigated VWs.

Much of the previous studies on social capital highlighted and investigated the positive influence on social capital generated by high level of interpersonal trust and social network ties (Coffé and Geys, 2007). While Portes (1998) argued that strong tied social group can provide various benefits to its members, but it may also restrict entry to and denies the sharing of these benefits to others and to non-members. This findings indicated that social capital is not necessary to be beneficial to everyone and suggest that interpersonal trust and social network tie may indeed two different form of social capital which may influence members in different way. This led to researchers to identify two forms of social capital, bridging (covering the informational benefits of heterogeneous network of weak ties) and bonding (covering the emotional benefits from strong ties) (Coleman, 1988; Putnam, 2000; Boyd and Ellison, 2007).

Studies of social capital in different VWs allow researcher to identify building elements of social capital such virtual platforms. For example, Boyd and Ellison (2007) study's investigated undergraduates university students uses Facebook found that Facebook platform has strong influence on generating and maintaining of social capital.

This study focuses on looking at whether the influence of social capital are different among VWs. Particularly, whether bridging and bonding social capital differs among different VW platforms — gaming VWs (GVWs), social VWs (SVWs) and Mixed VWs (MVWs) - on social capital.

Although there are few previous studies investigated social capital in VWs (e.g. Huvila, Ek, & Widén, 2014; Huvila, Holmberg, Ek, & Widén- Wulff, 2010; Reer & Krämer, 2014; Zhang & Kaufman, 2015), but only examine social capital development in one VW platform or one particular type of VW.

This research contribute by examine and comparing the social capital (Bridging and Bonding) on multiple VW platforms — world of warcraft (WOW) which representing GVWs, Second Life (SL) which representing SVWs, and Entropia Universe (EU) which representing MVWs.

## LITERATURE REVIEW

### *Social Capital*

The wide-spread of different VW platforms and the influence of these platforms on social capital have gained a lot of attention in the past few years (Trepte, Reinecke and Juechems, 2012; Reer and Krämer, 2014; Zhong, 2014; Smith, Smith and Shaw, 2017). The term social capital is often associated with Putnam (1995, 2000) in his study investigated the American society.

Social capital is described as the benefit and support (which include information, relationships, assistance, emotional support, and resources) people accumulate from their social relationships and networks within a given social situation, in which networks, norms, and social trust facilitate these coordination cooperation for this mutual benefit (Stanton-Salazar, 1997; Williams, 2006; Boyd and Ellison, 2007; Trepte, Reinecke and Juechems, 2012; Zhao *et al.*, 2016).

In some studies, researchers distinguished between the two forms of social capital determined by Putnam (1995, 2000), which are bridging (weak ties) and bonding (strong ties) (e.g. (Williams, 2006; Coffé and Geys, 2007; Trepte, Reinecke and Juechems, 2012; Reer and Krämer, 2014).

In group environment, through social capital members can share relevant information, guidance, and emotional support (Law & Chang, 2008; Moschetti & Hudley, 2015; Nov, Ye, & Kumar, 2012) to enable them to manage and overcome challenges.

Social capital also provides important collaboration and build relationship which is latent to individuals' daily life within the community members in VWs (Moschetti and Hudley, 2015).

**VWs**

The term VW has a diverse definitions, but generally this term used to describe a computer-simulated persistent spatial environment which provide a level of communication between multiplayer who are represented visually by avatars (Holmstrom and Jacobsson, 2001).

Avatars – in the content of VW – is a graphical user representation made by participant of the VW platform through which the participant can interact and communicate with the surrounding virtual object and with other participant avatars (Liu and Williams, 2008; Tikkanen *et al.*, 2009; Nah *et al.*, 2011).

VWs with it advanced interaction and communication infrastructure have become immensely popular, with around 1.4 billion registered users worldwide in 2011 (kZero, 2011). The most common VW types is GVWs and SVWs. GVWs are the virtual platform which mainly build for gaming purpose, in which users follow a pre-defined themes, these activities usually aims at completing quests or level-ups rather than social interaction, such as WOW, EverQuest, etc. (Jung and Kang, 2010).

While SVWs are the virtual platform which mainly build for socializing without any pre-defined themes and plots. For example, SL, IMVU, and There (Jung and Kang, 2010). GVWs with pre-defined themes and plots and pre-determined storyline still occupy the majority of VWs. However, SVWs provide a higher level of flexibility and freedom to the users, where users create their own experience with support of social interaction modules. These functionalities have dramatically increases the popularity of SVWs and with hence, provide a diversity in members' behaviour (Jung and Kang, 2010).

Through investigating the different VWs, there were some VW platforms which sits in a level between SVWs and GVWs in such VW users have a high level of freedom and flexibility in the VWs with a high level of social orientation. At the same time, they can play together to reach pre-determined storyline. This type of VWs will be called Mixed VWs (MVWs) (Nazir, Siu, and Hamilton, 2016). An example for a MVW is EU VW with its specific planet called "Planet Calypso".

Furthermore, the dynamic platform in the SVWs and MVWs make it suitable to support different virtual transaction systems, which is also called real-money trade (RMT) or real-cash economy (RCE). This kind of RMT platforms could include virtual currency transactions, virtual exchange systems, and/or virtual market places (Jung and Kang, 2010; Nazir and Lui, 2014, 2015; Nazir, Siu and Hamilton, 2016; Nazir and Man Lui, 2017). RMT is examine in another study (e.g. Nazir and Lui, 2014, 2015; Nazir, Siu and Hamilton, 2016; Nazir and Man Lui, 2017).

**Social Capital Types**

As discussed earlier, Putnam (1995, 2000) and previous studies (Table 31) classified social capital into bridging and bonding social capital. In which bridging social capital is developed in the communities involving information exchange and sharing without the support of emotional bond, this is related to the term used by researchers as "weak ties" (Granovetter, 1973; Coleman, 1988; Haythornthwaite, 2002, 2005).

On the other side, bonding social capital referred to strongly tied relations in which emotional support is included in the relationship within the community members (Boyd and Ellison, 2007; Steinfield, Ellison and Lampe, 2008; Huvila, Ek and Widén, 2014; Moschetti and Hudley, 2015).

*Table 31 Grouping Social capital Studies*

<b>Reference</b>	<b>Bonding</b>	<b>Bridging</b>
(Sheer and Rice, 2017)	✓	✓
(Huang, 2016)	✓	✓
(Reer and Krämer, 2014)	✓	✓
(Trepte, Reinecke and Juechems, 2012)	✓	✓
(Coffé and Geys, 2007)	✓	✓
(Williams, 2006)	✓	✓
(Putnam, 1995, 2000)	✓	✓

Other researcher (e.g. Adler & Kwon, 2002) classified social capital based on the internal and external relations of the community. In Adler and Kwon (2002) finding, internal relations is equivalent to bonding social capital and external relations is equivalent to bridging social capital.

Whether it is bridging or bonding social capital, social capital in general constituted by three dimensions/factors which are; cognitive, relational, and structural (Inkpen and Tsang, 2005; Wasko and Faraj, 2005; Wang and Chiang, 2009; van den Hooff and de Winter, 2011).

The cognitive dimension include elements related to common and shared things within the community members such as shared beliefs, culture, goals, language, practice, values, and/or vision (Inkpen and Tsang, 2005; Striukova and Rayna, 2008; Wang and Chiang, 2009; Alqithami and Hexmoor, 2012; Lefebvre *et al.*, 2016)

The relational dimension included elements related to personal relationships that develop over a number of communication and interactions (Granovetter, 1973), these elements such as identification, norms, obligation, reciprocity, and trust (Blanchard and Horan, 1998; Law and Chang, 2008; Alqithami and Hexmoor, 2012; Lee, 2014; Zhong, 2014), where trust is an essential element of community relationship (Anderson and Narus, 1990; Rousseau *et al.*, 1998).

The structural dimension include elements related to the connection and ties with community members (Coleman, 1988). These elements such as network configuration (Chung, Nam and Koo, 2016) and network ties (Lin, 1999; Striukova and Rayna, 2008; Hau and Kim, 2011).

*Online/Virtual Social Capital*

Researchers sort to understand the positive and negative influences of increasing virtual platform usage on social relationships and social capital (Huvila *et al.*, 2010; Reer and Krämer, 2014; Zhang and Kaufman, 2015). Some research findings show negative social effect of online platforms on social capital (Kraut *et al.*, 1998; Nie and Erbring, 2002; Lee and Kuo, 2006). Other research found positive social influence of online platforms on social capital (Reer and Krämer, 2014; Tsai *et al.*, 2014; Warren, Sulaiman and Jaafar, 2014).

Different VW users are likely to have different motives when engaging in different types of VWs. This likely influences the way VW users interact and communicate with each other and their VW environments. It also likely influences the way they build social relationships which in-turn often effects the building of social capital (Shiue, Chiu and Chang, 2010; Hau and Kim, 2011; Chung, Nam and Koo, 2016).

Reer and Krämer (2014) found some online and virtual activities help strengthen and build social capital. For example, these virtual communication activities can take place via instant messaging (IM), chatting, emailing, and/or video conferencing. While other activities such as personal online/virtual shopping, online banking, and/or video streaming can isolate a user and weaken the community’s ties and hence its social capital (Reer and Krämer, 2014).

Steinkuehler and Williams (2006) studied massively multiplayer online-games (MMOs) and found a positive influence on social capital. Other studies support that VW platforms provide a community meeting place for users with diverse backgrounds and values to communicate and know each other and to foster a bridging form of social capital. Williams et al. (2006) and (Kobayashi, 2010) investigated WOW and a Japanese gaming VW platform. Both found gaming VWs platforms provided a media where users were able to communicate, meet new people, and extend their social networks. This again built a bridging social capital between users.

Although many studies find the formation of bridging social capital is inherent and is a norm within groups. Other studies suggest building strong ties (or bonding social capital) in a VW platform is often possible (Trepte, Reinecke and Juechems, 2012). Reer and Krämer (2014) in their review suggest studies confirm the possibility of building bonding social capital in gaming VW can also occur. For example, Steinkuehler and Williams (2006) find users of Massively multiplayer online-games (MMOs) can build stronger relationship, but these cases remain rare. Williams et al. (2006) and Siitonen (2009) provide further supporting evidence that bonding social capital can occur in VW platforms. *Table 32* summaries the above finding.

*Table 32 : Bridging and bonding social capital in VW platforms*

	Targeted VW	Build bridging social capital	Build bonding social capital
(Williams <i>et al.</i> , 2006) - WOW	WOW	✓	✓
(Kobayashi, 2010) – Japanese online game	Japanese online game	✓	✗
(Trepte, Reinecke and Juechems, 2012) - e-sports clans	e-sports clans	✓	✓
(Siitonen, 2009)	Anarchy online	✓	✓

Lin (1999) examine friendship in VW communities and found friendship strengthen the community’s relationship and boosted the formation of social capital. Steinfield et al (2008) found SMNs usage can assist in psychological development of users. This enhances their sense of self-respect and thus contributes towards a stronger community relationship and a stronger social capital. In summary, research continues into influence of SMNs and VWs and on the building social capital. As the interactive environment in VW platforms advance, improved engagement and socializing channels may also strengthen the social relationship of users in the community (Ostrander, 2008; Nardon and Aten, 2012). This in-turn fosters the growth of bonding social capital (Williams, Yee and Caplan, 2008; Siitonen, 2009) or transforms bridging social capital towards bonding social capital (Donath and Boyd, 2004).

**METHODOLOGY**

*Instrument Development*

This study examines whether bridging and bonding social capital differs among different VW platforms. The targeted participants are active users of Second Life (SVM), World of Warcraft (GVM) and Entropia Universe (MVW). Hence, an online survey is an appropriate research design. This allows the researcher to reach global population of the targeted VWs.

The online survey is distributed through survey monkey. The online survey (10-15 minutes 5-point Likert scale) remains live for a period of three months. The online survey URL is placed and shared through SL, WOW, and EU related community platforms, such as Facebook, forums, and instant messages (IM) within the VWs.

To operationalize the constructs, measurement items are compiled and adapted from validated instruments used in previous studies. Specifically, we adapted bridging social capital items questions from Marczewski (2015) and items for bonding social capital from Hassouneh and Brengman (2014), Ryan, Rigby, and Przybylski (2006), Zhang and Kaufman (2015) (refer Appendix A).

### Data Collection

A total of 613 responses were received. After eliminating duplicate and incomplete responses, the final usable sample size for this study was 274.

SPSS 22 is used to perform factor reduction and to validate construct reliability. Cronbach's alpha of each variable was greater than the recommended 0.60 (Hair *et al.*, 2010).

### RESULTS

Table 3 summarises the demographics of the sample (n=274) from SL, EU, and WOW. Male (57%) outweigh female (43%) across these VWs platforms. About 79% of the VW users are under 44 years.

Table 3: Respondent Demographics (profile)

Demographic Measure	Percentage (%)
Gender	
Female	43.1%
Male	56.9%
Age	
18 to 24	23.7%
25 to 34	30.7%
35 to 44	24.8%
45 to 54	14.6%
55 or older	6.2%

### ANOVA Results

To examine the research hypotheses, ANOVA with post-hoc analysis was conducted. The results are shown in Table 33. This compares the bridging social capital and bonding social capital in the different VW platforms (SL, EU, and WOW). The results indicate there is no significant difference in bridging social capital between different VW platforms. However, considering bonding social capital, there is a significant ( $P < 0.05$ ) difference between EU and both SL and WOW.

Table 33: ANOVA with Tukey HSD Test for Social Capital (Bridging and Bonding)

Construct	Main VW	Compared VW	Mean Differences	Std. Error	Sig.
<b>Bridging</b>					
Bridging	SL	EU	.153	.113	0.36
		WOW	-.033	.102	0.94
	EU	SL	-.153	.113	0.36
		WOW	-.186	.106	0.18
	WOW	SL	.033	.102	0.94
		EU	.186	.106	0.18
<b>Bonding</b>					
Bonding	SL	EU	.831*	.139	0.00
		WOW	.126	.125	0.57
	EU	SL	-.831*	.139	0.00
		WOW	-.705*	.130	0.00
	WOW	SL	-.126	.125	0.57
		EU	.705*	.130	0.00

\* The mean difference is significant at the 0.05 level

A plausible reason for differences in bonding social capital between EU and both SL and WOW, is that EU is a platform with mix form of socializing and gaming where users may develop a specific social capital that is different that game oriented only platform and social oriented only platform.

### CONCLUSION

The study of bridging and bonding social capital in a particular VW type or platform has been studied (Reer and Krämer, 2014; Yoon, 2014; Zhong, 2014). However, whether bridging and bonding social capital differs among different VW platforms remains inconsistent.

It remains worthwhile to explore the relationship and influence between different VW types and their effect on bridging and/or bonding social capital. A better understanding of such influences allows developers and business' to offer customized products and services. This enable the development of a strong social capital relationships among VW platform users. This may in-turn build customer trust and/or loyalty.

Overall this research study concludes differences in bonding social capital exist across different types VWs. In contrast, there is no significant difference in bridging social capital.

This finding addresses the gap that differences in social capital do exist between gaming, social, and mixed VW platform users.

### Limitations & future research

This study chooses only SL to represent SVWs, only EU to represent MVWs, and only WOW to represent GVWs. Future extension studies can include additional VW platforms. This can validate and provide further understanding and generalization.

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APPENDIX A

1. Which one of the following virtual worlds do you use mostly

- Second Life
- Entropia Universe
- World of Warcraft

2. What is your gender?

- Female
- Male

3. What is your age?

- 18 to 24
- 25 to 34
- 35 to 44
- 45 to 54
- 55 or older

4. In the VW, I like:

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
to help others in the VW	<input type="radio"/>				
not to share knowledge with others	<input type="radio"/>				
breaking rules	<input type="radio"/>				
volunteer my time to the communities	<input type="radio"/>				
to donate rewards to help others.	<input type="radio"/>				

5. In the VW, I find it easier to:

	Strongly agree	Agree	Neutral	Disagree	Strongly disagree
start a conversation with strangers than in real-life	<input type="radio"/>				
have good friends	<input type="radio"/>				
talk more about personal issues with VW friends than in real life	<input type="radio"/>				
remove some of my self-restraints	<input type="radio"/>				
have a lot of friends	<input type="radio"/>				

# Exploring the Implications of Perceptive Relationship-Marketing toward Mobile Self-service Technology of Catering Experience

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## Abstract

Self-service technologies (SSTs) and mobile self-service technologies are important tools for today's business services. This study applied Kano model combines means-end chain(MEC) theory in the setting of catering operations to reveal how the attributes of MSSTs can build, maintain and attach the relationships between restaurant owners and consumers, in order to develop effective relationship marketing strategies.

Through by using the laddering technique, the in-depth interview transcripts were content and reliability analyzed to construct the hierarchical value map for revealing consumer's psychological perceptions of relationship building, maintenance and attachment. Both Kano model, understand the foregoing classification of variable quality, to define quality content, foregoing analysis results the conclusion by means of marketing and advertising strategies to develop policy and design of the products and services of reference. This study analysis methods could be applied to the service industry, such as hotels, restaurants, theme parks, future researchers may consider using this research analysis method study of the different service industries.

**Keywords:** *Means-end Chains; Mobile self-service technologies; Relationship marketing*

## INTRODUCTION

### 1.1 Background and Motivation

In recent years, with the rapid growth of domestic economy and the rapid development of information technology, many enterprises have introduced suitable information technology in a competitive business environment as a different segment from traditional business services. characteristics, strengthen their competitive advantage and therefore all kinds of self-service technology (self-service technologies, SSTs) was due to be born. Google Inc. in 2016, the "Consumer Insights Report" and "Taiwan Digital Consumer Research Report" survey data show that Taiwan's smart phone penetration rate has reached 82% of the high, of which 25-34 year-old young users it is almost to have one, that is, the smartphone penetration rate close to 100 percent as much as (Google company, 2016); national communications Commission (NCC) statistics are shown, in August 2015 deadline for the statistics, Taiwan 4G users has reached 8.66 million (the national communications Commission, 2015), in other words, people use smart mobile devices have become more frequent, ie smart mobile devices have become a necessity for people in everyday life, combined with Taiwan's wireless network The popularity of the road, the convenience of the mobile network has been unable to say. Therefore people from daily life behavior patterns already "priorities for action" (Mobile First) gradually shift into "action unique" characteristics (Mobile Only), and entertainment, socializing, shopping and other services usage behavior, have been accustomed to in the media all kinds of mobile devices rapid deployment (Institute for information industry FIND, 2016). In summary, accompanied by APP mobile devices, SSTs also conform to the popularity of mobile phones and consumer trends change, and further action to be derived from their use self-service technology (mobile self-service technologies, MSSTs ). Many businesses but also for the universal qualities App and commercial potential, the introduction of a variety of location-based services (location-based service), namely "Through return phone GPS location, providing recommend nearby restaurants, public transportation to take place or promotions information activities and

other services "(Institute for information industry FIND, 2017). Most studies only investigate SSTs in the importance of relationship marketing construct, document mentions the use of less importance MSSTs relationship marketing to mobile commerce (m-commerce) , as well as how to set up businesses and consumers to promote the use MSSTs between "Relationship building " of. Therefore, this study through various features of the property MSSTs understand " building, maintain and attachment" relationship between business and consumer marketing perception connotation.

Since ancient times, "people eat food for the day", the nature of the human nature is the basic physiological needs of the characterization, but for many years the development of food culture, with the diversification of consumer behavior, people's demand for food has been to meet the basic needs of survival of the traditional diet behavior, into the pursuit of high-quality food culture behavior, such as dining environment, quality meals, etc. (Zhuangzi Li, 2012). The above-mentioned argument is fully reflected in the fierce competition situation in Taiwan's food and beverage market in recent years, supplemented by the Internet era of food and beverage transformation, for the traditional dining brought buy, take-away, management software and other business challenges. Now holdings of smart mobile devices more and more, catering to business competition has extended to the mobile phone platform, dining app then timely response born, become an emerging trend in the restaurant industry business model. Through the Institute for Information Industry in 2010 networking technology with an indoor location-based services, import Din Tai Fung in Taipei 101 shopping guide service waiting position, simultaneously enhancing operating performance and reduce consumer department store waiting for the restaurant to complain. (1982 Gutman,) theory, started by the consumer perception connotation based method combined with end chain (means-end chains, MECs) to learn more about how consumers generate content and relationships of the store, this study uses relationship marketing, consumer analysis "product knowledge - personal values" among those associated with the product, in order to understand the relationship between businesses and consumers, "the building, maintenance, attachment" important variable modes. Therefore, when a consumer uses MSSTs patterns of consumption for consumption, it can be more clear positioning of the relationship marketing connotation MSSTs.

In addition, Kano two-dimensional quality model is mainly to assess whether the product attributes meet consumer demand, and whether consumer satisfaction with the product attributes content, meets by product attributes and customer satisfaction, carried out the five attributes of quality content classification. Therefore, with the method using object model quality Kano chain theory, the consumer can understand the use MSSTs, positioned in the service properties Kano quality classification, mean chain theory and use object model with Kano, how to produce the consumer may be constructed MSSTs And the relationship between the business, and how to maintain and produce attachment relationship, but also understand the important relationship between the content of the content of the connotation of the content, in order to more specific action self-service technology with food and beverage experience products and advertising marketing strategies and other related content.

## 1.2 Objective

In the face of competitive food and beverage market and the rapid development of science and technology, consumers are no longer satisfied with the traditional dining experience, the pursuit of innovative dining experience, leading the catering industry must continue to introduce their food and beverage content and operating service model. That is, how the catering industry in the homogeneity of the food and beverage sector to meet the changing needs of customers and attract more consumers to spend, to achieve the goal of enhancing the overall operating profit, restaurant industry has been an in-depth discussion of important research and development issues.

Based on the above, the purpose of this study is as follows:

Analysis MSSTs tool "relationship building" in, "the relationship to maintain," "relationship attachment" relationship between the different stages of the property and derivative of its relationship results and value, and then infer enterprises refer to goods and services design, and its related products and advertising Strategy Framing reference.

" Relationship building " analysis, "relationship maintenance", each stage of the relationship "relationship attachment" MSSTs product attributes two-dimensional quality assessment, so as to provide food and beverage industry to develop more clearly the product strategy.

This study will combine Means-end Chains and Kano two-dimensional quality analysis model, and by the characteristics of each stage of the relationship marketing and so on, export consumer spending deeper

feelings, and then push play out MSSTs services, as interpreted MSSTs product planning analysis mode Of the reference.

## Literature Review

### 2.1 Mobile Apps (mobile applications; APP)

With the rapid development and popularization of information technology and mobile devices, creating a mobile app (mobile application, mobile app, apps ) are highly developed. App for the Application of abbreviations, in a broad sense in the computer software are known as App (saying Lee, 2013), for example, commonly used instrument software Word, Excel and Power point etc., due to the popularity of smart mobile devices, now refers specifically to running on smart mobile devices (such as smartphones or tablet) application (Ye Zhezong, Lin Jingyi, Chen Xiuhui, 2013) on, the user is free Wi-Fi through the app store or even to pay to download and use mobile apps The

APP Store is Apple's app store platform for iPhone, iPad and iPod Touch and other products built using iTunes browse and download produced by the developer app. Users can use the different circumstances of the release, free or paid download. The app type includes social, entertainment, dictionaries, business, gourmet dining, sports, newspapers and magazines and many useful software. Apple's profit from the sale of the App Store application is divided into 30% of sales, developers get the remaining 70%.

Firstly, this model of Apple APP Store, and then after that Google has launched the Google play store for its mobile operating system Android, users can also download free or paid mobile apps through the Google play store to Android or Google TV, etc. means the mode of operation is substantially the same APP Store. Google play store is divided into two categories: apps and games and movies, books, newsstand, content includes shopping, map navigation, gourmet dining, entertainment, family, education, health care, photography, shop has been published more than 2.2 million applications program, downloaded over 50 billion times.

Usage behavior smartphone app for consumers to understand how lifestyle perspective of the user to allocate limited time, energy and money (name Chen Wei, 2012). Explore the mobile app behavioral intention and action combined with the value of trust, subjects were to have used APP users high-speed rail development in Taiwan (Liang Huan Yu, 2013).

Affect consumer intention of APP, cost factors including perception, social influence, perception of fun, innovative and trial of individuals can wait (Ye Zhezong, Lin Jingyi, Chen Xiuhui, 2013). Another research community APP places as the main subject for discussion (saying Lee, 2013). According to international market research consultancy creation in 2014, the survey is displayed for the user to hold a smartphone it, App type more commonly used, mainly focused on "Social / instant communications" (57.3%), and so many actions studies have switched applications related to the social / instant communications.

### 2.2 Self-service Technologies( SSTs)

Meuter, Ostrom, Roundtree and Bitner et al. 2000, self-service technology (SSTs) proposed definition, consumers use self-service technology is platform independent information technology and the services required to complete the transaction, and the transaction during an employee or service provider does not need to participate, to meet the needs of self (Lin Shengwei, Su Yu Jun, 2016; Chen Jinhong, 2015). So the difference is defined, self-service and general services whether "interact with people." (Liu Liwei, 2006; Chen Jinhong, 2015) is whether "the use of technology interface" and.

In recent years, the basic wage of labor has been improved due to the increase in the basic salary of labor as stipulated by the Labor Standards Law, so that the service cost of services such as restaurants, restaurants and airports has more and more trends in the use of self-service facilities. Expenditure costs, self-service technology can also improve the speed of service delivery and accuracy. In general, SSTs including the Internet, interactive kiosks, interactive voice system and mobile services and other four categories (Castro, Atkinson, and Ezell, 2010; Lin and Hsieh, 2011; Lin Jun liter, Lin Cheng-Yu, Yi Zhou Enlai, 2016).

Self-service technology in the marketing services sector is already a mature area of research literature in the past, many scholars to explore its innovative features are directly or indirectly affect the customer wishes to use SSTs also show plays in the whole process of service delivery important role (Curran and Meuter, 2005; Curran , Meuter, and Surprenant, 2003; Dabholkar, 1996; Dabholkar and Bagozzi, 2002; Meuter et al, 2000.). Many studies have focused on exploring the use of SSTs impact on the results of customer behavior, including:

customer perceived wait time (Weijters, Rangarajan, Falk, and Schillewaert, 2007), customer satisfaction / dissatisfaction (Holloway and Beatty, 2008; Meuter et al, 2000;. Weijters et al , 2007), as well as customer loyalty (Selnes and Hansen, 2001). . In addition, due to the development of the Internet, many past studies have focused on exploring how customers evaluate service quality website (E-service Quality), and the development of a suitable scale (Parasuraman, Zeithaml, and Malhotra, 2005; Wolfinbarger and Gilly, 2003; Zeithaml, Parasuraman, and Malhotra, 2002 ). However, due to the current SSTs species are not only limited to the Internet, customers may use different SSTs to complete all of the services, so Lin and Hsieh (2011) developed a new SSTs service quality measurement scale, integrated measure of the company SSTs overall quality of service (Jiun liter, Lin Cheng-Yu, Yi Zhou Enlai, 2016).

## 2.3 *Catering Experience*

### 2.3.1 Experience

Experience means that people face the products, services and business when the formation of "will stay in the hearts of customers," the impression that people will be all sensory information together to form feelings. The business experience is a combination of the value of the consumer's acceptance of the process and the resulting memories in the event that the producer and the consumer co-create a charismatic activity. Experience is the individual after the external stimulus, through the feelings of the process of consciousness generated by the psychological reaction, this reaction is usually induced, rather than spontaneous response, and the reaction and the event has a subordinate or related relationship.

Pine II and Gilmore (1998) is considered the economic model from the early agricultural economy, after the industrial economy, service economy, and now the experience economy; economic product of these four stages are Commodities, goods, service, Experiential, in which the experience economy arranged a cozy atmosphere and elegant environment, so that consumers enjoy the five senses levels of intimate products and services with the highest added price characteristics (Wang Hongzhi, Tangguo Hao, Li Junxian, Chen Yi ensemble, Lai Jian It was, and Cai Ming, Liu Weixuan, 2010).

### 2.3.2 Food consumption experience studies

In the past, the study of the consumption experience of food and beverage is different, but the meaning is similar, which means that in the process of catering consumption, customers and meals are common out of the result, which includes tangible and intangible products, such as: quality of service, food quality, value for money, as well as interpersonal atmosphere, etc. (Johns and Tyas, 1996; Yükseland Yüksel, 2002; Hancfors and Mossberg, 2003; Lord et . al, 2004; Quan and Wang , 2004). Although food consumption in the travel experience during the role is important (Sheldon and Fox, 1988; Hall et al, 2003;. Quan and Wang, 2004), but the limited number of studies related to food consumption experience, and in among the various existing literature scholar benchmark for food and beverage consumption experience also vary (Liu Yuan, Zhan Peiwen, Su Wenyu, 2008).

## 2.4 *Relationship Marketing*

Relationship marketing is to pay attention to and get along with customers, the purpose is to understand the needs of customers and self-service content with each other. And relationship marketing is to establish and maintain long-term relationships with customers, marketing methods carried out a series of customer-centric design, and these marketing methods at any time due to changes in market customers to make changes needed (Lai right Fu, 2008) The That the relationship marketing is to establish, maintain and strengthen the relationship between the customer, to achieve through mutual exchange and fulfillment of promises (Halimi et al., 2011) .

According to Berry & Parasuraman (1991) proposed a hierarchical relationship marketing with customers combined with three kinds of lies build customer tiers (a) financial bind, offering incentives on price, to ensure customer loyalty and encourage customers to spend more goods company, the average customer to become customers often buy; (b) in conjunction with the financial and social, with individualized service delivery, the customer will be relatively sense of trust and satisfaction on the company and that there is good quality relationship with each other; (c) the overall service delivery, further to a structured approach integration and set long-term stable relationship (Huang Jianwen, Cai Xinrong, Jia United States, 2014) with the customer.

## 2.5 *Means-end Chains( MECs)*

"Means-end Chains" of this theory in 1982, the year of the proposed Gutman, consumer advocates when making decisions on the behavior of their heart tangible products or intangible services, give them each a

different meaning, factors that influence these decisions for products Attribute, and consumers in the consumer products after the feeling is the result, then based on the feelings of the above can meet the value of mutual psychological relationship between the psychological perception. The basic structure of the above object is the method of chain: attributes (A), the consequences (C) and values (V), shown in Figure 2-1. Olson and Reynolds further explained in 2001, "method" (means) refers to a product or service consumers actual contact, and "Purpose" (end) may be regarded as the value of personal inner situation, meaning a through understanding of consumer choice The cause of the product, and the underlying structure from which the value is obtained, further illustrating the behavior of the consumer. Therefore, the purpose of the purpose of the chain model for marketing and advertising strategies, brand positioning, etc., to understand the customer in the choice of products, services and other acts considered factors.



Figure 2-1 Means-end Chains model

Researchers often use Reynolds and Gutman proposed in 1988 "laddering technique", and draw hierarchical value map (HVM), perceptual map for consumers to purchase psychological perception of the process of goods to be interpreted, And then derive and develop products and advertising related to the strategic content. For "property", "result" and "value" at all levels Jieke subdivided into two parts, further more detailed construction of the "Means-end Chains" content model, shown in Figure 2-2.

(1). Attribute

attribute that is characteristic of the product, by means consumer goods or services directly feel the perception of content. Product properties can be further region specific features into concrete attributes and abstract attributes, specific properties such as appearance, price, brand, etc., can be clearly described, a more objective portion; abstract attributes seller quotient reputation, brand image, more subjective part, this is the most sensible of consumer (Zhuangzi Li, 2012).

(2). Consequence

Consumers from the product attributes obtained in the results of psychological feelings, this psychological feelings may be positive or negative, consumers will be based on the results feel to measure the product, not just the product itself to evaluate. Feel the results can be divided into functional consequence and psychosocial consequence, functional consequence means the immediate, concrete results can be seen by the product attributes directly evaluated, such as a drink to quench their thirst; psychosocial consequence it is the consumer after the use of the product after the emotional or abstract response, including the consumer's own psychological perception and other people's views, such as wearing brand-name clothing can attract other people's attention. So feel the result is an intermediate-level variables linked product attributes and personal values (Peter and Olson, 1993; Lin Qinfeng, Ye Mingyi, Qiuzhao Min, 1999).

(3). Value

Value is the highest level Means-end Chains is also more abstract state, is the consumer of consumer products to meet the expected life of the inner state of consciousness performance, value can be divided into instrumental value and the terminal value. Instrumental value is the consumer's own personal values, such as independence, self-confidence; terminal value is the ultimate goal, such as satisfaction, get others to agree, etc. (Rokeach, 1973).

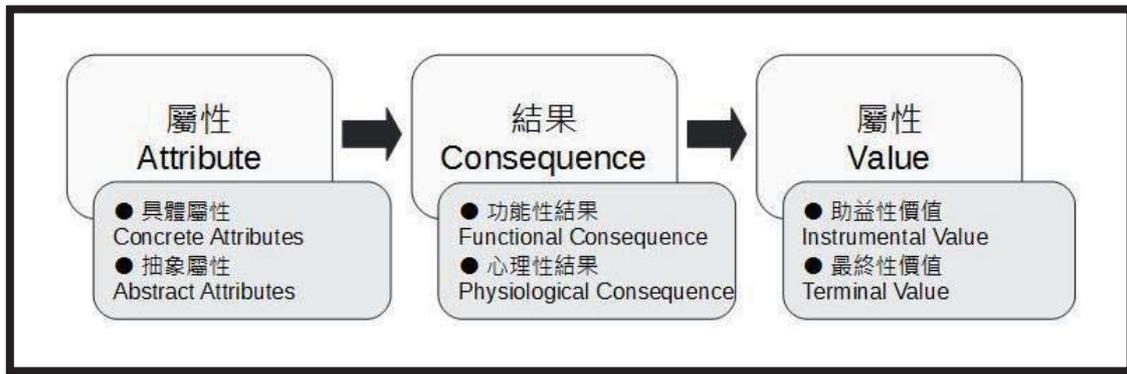


Figure 2-2 Consumer perception Means-end Chains' model

## 2.6 Kano two-dimensional quality mode (Kano model)

Kano quote from the psychologist Hertz Berger the proposed use of the incentives of employees' motivation - hygiene theory, "named for quality improvement," the quality of the "ideas and Dr. Kaoru Ishikawa, again given the quality and charm of course name quality (Kano et al., 1984) . And in 1984 with the Seto Lok Nobuhiko, Fumio Takahashi with a new concept and empirical research "two-dimensional quality mode" of the official presentation. Kano two-dimensional quality mode the horizontal axis represents the elements of quality have an extent, coordinate on behalf of the customer satisfaction degree, Kano quality factors into attractive, one-dimensional, must-be, reverse and indifferent five configurations , The five quality facets are described as follows:

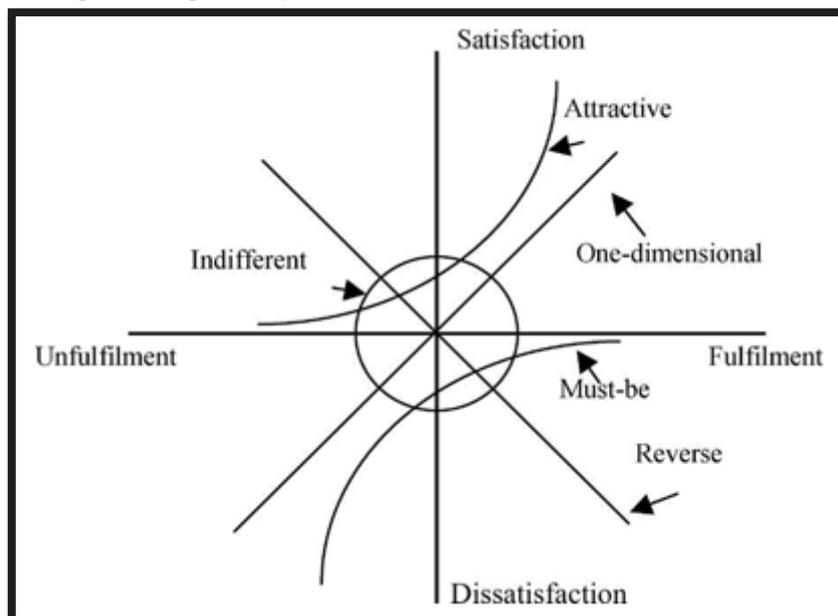
(A) Attractive: When sufficient quality factors, the customer will be satisfied, when insufficient quality factors, will not lead to customer dissatisfaction. If the enterprise can fully grasp the charm of quality elements, as long as the quality of the elements to enhance the adequacy, customers can be satisfied with the substantial increase.

(B) One-dimensional: When sufficient quality factors, the customer will be satisfied, when elements of insufficient quality, the customer is not satisfied with. That is, whether the quality of sufficient or customer satisfaction is not satisfied with a linear relationship.

(C) Must-be: quality elements should be adequate conditions, but will not cause customer satisfaction, quality factors when insufficient, that will immediately lead to customer dissatisfaction.

(D) Reverse: When sufficient quality factors, the customer will be satisfied, when elements of insufficient quality, the customer will be satisfied.

(E) Indifferent: sufficient quality factors or not, will not cause customer satisfaction or dissatisfaction. (Yi, boxes, Cai Hongren, Zhang Jiaming, 2013)



## Research Methods

### 3.1 Research Framework

The main purpose of this study means-end chains (MECs) and Kano analysis mode For consumers and businesses between the "relationship building, relationship maintenance, the relationship attachment" psychological perception of product characteristics and variables, is divided into two stages ( Study 1 and Study 2) to collect work samples. The first phase (Study 1) and collect relevant documents referred to in the relevant variables, and by secondary data aggregated results, pre variables measured, and then extract important research variables using the consolidation method results in-depth interviews, relationship marketing is the main purpose and method combined with the use of chains, thereby analyzing the respondents for each service class characteristic kinds of food provided by APP and evaluation of the content "attribute (a) - consequence (C) - value (V)" arising through its service features inner feelings; the second phase (Study 2) is carried out visits to a structured questionnaire to collect data through content, and content analysis method and step-law, confirmed the relationship between variables link, the final result will be two phases of construction of the inner consciousness of consumers As shown in the hierarchical value map (HVM) .figure 3-1 is study architecture.

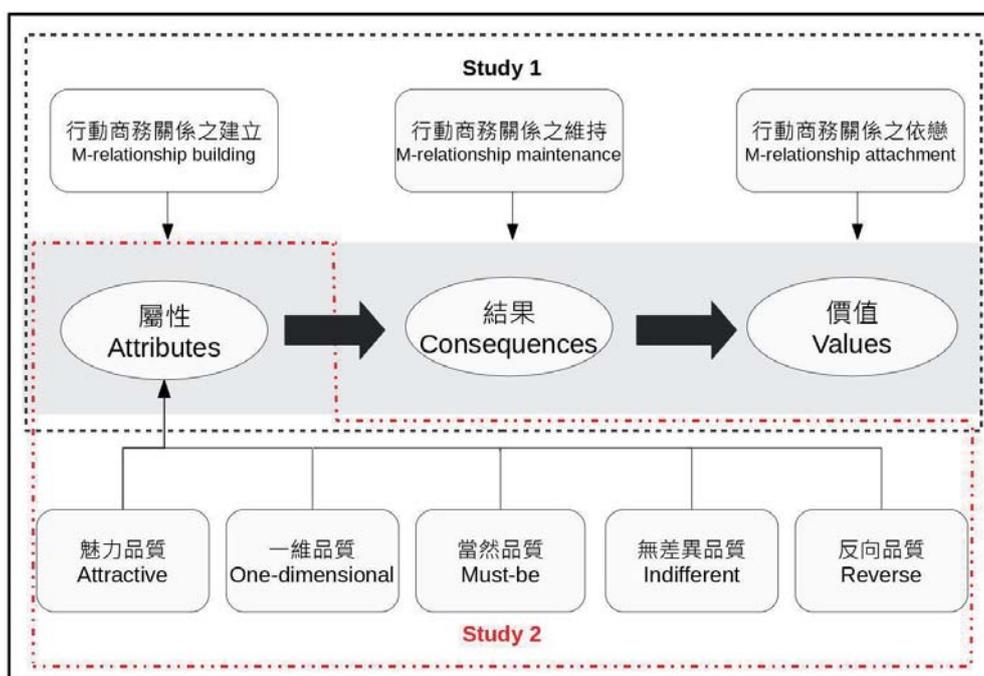


Figure 3-1 research framework

### 3.2 Sample source and Sampling method

The first phase of this study sample sampling work, mainly in the collection of relations MSSTs establish / maintain / attachment variable content into three categories, with reference scholar Gutman (1984) of the recommendations, a method for the purpose of research law in-depth interviews chain sampling method, the most appropriate subject the number of visits of about 30-60 people, and is limited by the restrictions of time and manpower, so the stage is expected to take several samples of 40 people, a purposive sampling method, and can not rule out those with experience of research topics, in order to speed up data The correctness of the collection, and will be based on disposable income, gender and age for the distribution of samples. In view of the APP with SSTs more popular with younger use, the survey sample and reinforce research will be mainly younger, younger consolidate research will be defined as high school graduation (or the same old person) to 35 years of younger respondents to choose person, face to face soft staircase method interviews with time are set at about 40-60 minutes, after detailed through individual interviews, respondents expect available consumer purposes to be achieved in the course of APP, values and considerations, etc. Perceived content.

The second stage will be the first to review the content of the first phase of the collection of the contents of the variables, through the content analysis method, the integration of variables, such as "beautiful" and "beautiful" or "convenient" and "convenience", Whether or not attributable to the same variable content. This phase will be paired with a sample of about 300 copies of a structured questionnaire gathering, to investigate the use of convenience sampling methods, such as the Internet questionnaire, actually paid and so on, to really grasp every ethnic consumers, so respondents will include student groups, Social factors and housewives, etc., and the information obtained by factor analysis methods and reliability analysis methods to reduce the homogeneity of the variable content to facilitate the formal questionnaire release, the respondents can clearly link the purpose of the target chain "attribute - results - Value" of the hierarchical relationship.

### 3.3 *Research variables Source*

This study is mainly based on the method of target chain theory, and the method chain has been used in many studies, especially in the field of marketing is often used, so through interviews with respondents face to face interviews, understand the use of catering when the class APP, in relation to building / maintain relations MSSTs overall service attributes / attachment relationship of the three stages of preferences (attribute) variable content and services at each stage whether the preference attribute content to meet consumer's consumption results feelings (consequence) and value connotations(value). Of which the value of variables in addition to in-depth interviews made variable, but will also be taking into List Kahle, proposed in 1986 of Values (LOV) 9 on value of scale, variable content are " self-respect," " being respected "," self-fulfillment "," sense of belonging "," excitement "," fun and enjoyment of life"," warm relations with others, "" sense of accomplishment "," security ", often used to study the value of the previous nine Objective chain. "build relationships","maintaining relationship","relationship attachment" MECs of three main methods to attribute/consequence / value (A / C / V) variable as a reference basis for the variable extraction work.

### 3.4 *Data Analysis*

#### 3.4.1 *laddering technique*

1988 proposed by Reynolds and Gutman laddering method Construction of "property — — result worth" after the contents of the link structure of consciousness, many ways to research and analysis purposes chain will often work to draw graphics using perceptual content staircase method, that is perception He said the class diagram or hierarchical value map (HVM). Because consumers do not have a specific method and purpose link for the product's "means-end chains", how to guide the content of the product, the result and the intrinsic value of the consumer's mind, and then complete the purpose of the method chain structure, that is, for the purposes of the main staircase method (Lin Qinfeng et al., 1999).

Interviews embodiment staircase method can be divided into two kinds, one for soft laddering method, a process step of hard (hard laddering) (Veludo-de -Oliveira et al., 2006). The soft ladder method is mainly one-on-one interview, to understand how the subjects use the product's attributes to meet the value of self, in which the interview process needs to explore in depth, and continue to tap the value of the hearts of respondents, have the opportunity to ask the interviewer, in order to discover more data available for analysis, and the test subject who gradually brought ACV link structure (Reynolds & Gutman, 1988; Lin Qinfeng et al., 1999). The hard ladder rule is a questionnaire survey or computerized form, allowing the subject to fill in the order of attributes, results, and values in a hierarchical order, but this approach is suitable for research that is more informative, when a large collection of sample data, or more prone to loss on the questionnaire did not ask additional information to the other items (Ter Hofstede et al., 1998 ). In this study, the use of Kano two-dimensional quality analysis methods and relationship marketing assistant means-end chains, the combined use of mobile technology and self-service dining experience consumer perception study conducted analysis of relatively rare, it is in the variable sources more inadequate, and due to the depth of the soft ladder method, the interviewer can get more information. The interviewer can also help the interviewee to do the abstract thinking of the attribute link, which will be subject to the study of the subject variable. Therefore, this study will take a soft ladder method for a deep interview, collect the information of this study.

#### 3.4.2 *content analysis*

Content analysis is the social science research, conducted data analysis is an important method for the study of qualitative research methods often end chain also uses content analysis. The method for finishing the content of the text after substantial articles or oral, objective and the classification system right amount of research methods (Berelson, 1952). Content analysis is widely used in the analysis of information content

analysis, especially for a large number of dissemination of information related to the content of the study is often used. Content analysis of advantages such as having to explain, predict or control functions, but it is special because the object analysis data can be text, images, sound, etc. (Babbie, 1997). A method for detecting properties attributes / results / value (A / C / V) of the variable coding, etc. In this study adopted content analysis.

### 3.4.3 Implication Matrix

Objective correlation matrix of the chain attributes / results / value (A / C / V) three times associated variable matrix, the matrix is a systematic, integrating all times is an important tool in the link step, the staircase method to collect after the summary of the variable type table, and then to analyze the content analysis of the number of associate and presented in a matrix, and as a draw hierarchical value map (HVM) of the basis (Reynolds & Gutman, 1988) , As well as an important step in translating qualitative interviews into quantitative data. In the whole matrix, the higher the number of variables and variables, the stronger the relationship between the two variables, through which the variables perceived by the respondents are collated to facilitate the plotting of the values between the variables The

### 3.4.4 Hierarchical Value Map( HVM) and the cut-off point for statistical

Log in and operation of the link established in this study " attribute (A)- consequence (C) - value (V) " using the ladder method. And using the relationship matrix summary table (summary implication matrix) to count "attribute (A) - the consequence (C)" and "the consequence (C) - the value (V)" the number of links. Recalculation of the number of links cut point value (cut-off-value) in the table through the statistics, the value plotted as a criterion of the hierarchy of HVM.

Within the correlation matrix summary table contains the number of links between all variables in the choice of cut-off point values shall establish cut-off point (cut-off) when the draw size value hierarchy chart, this study cut Pieters, Baumgatner and Allen, proposed in 1995 Point calculation method, according to the overall relationship to explain the ability as a cut value. Its implementation and calculation method with the steps of: (1) The data collection is completed, and the contents of the analysis, A - C - linked V of the tabular form sorted out correlation matrix summary, in the form of figures 1 ( The cut-off value is 1), indicating that the number of links between variables is 1. (2) No. of active cell the total number of cells connected to a truncated point; (3) No. of active cell as a proportion of all cell is the effective number of cells divided by the intercept value the total effective number of cells; (4) No. of active cells as a proportion of all cells mentioned at least once an effective number of cells to intercept value divided by the value of the effective cut point grid (or more) 1 number; (5) No. of active linkages as a proportion of all linkages coupling was divided by the total number of times the value of the intercept point link number. A representative interception value is used as a standard for drawing, based on the relationship between "one effective rate" and "link rate", and is plotted on the number of links.

## Expected Results

In this study, we use the MSSTs tool, which has been used as the research object, to carry out the relationship between "relationship building", "relationship maintenance" and " relationship attachment" by the method of target chain theory and the depth of interview with ladder method. Product quality variables to explore, while the use of Kano two-dimensional quality analysis model to understand the quality of the variable classification, in order to define the quality of the content, the following is the expected results of this study:

"relationship building" analysis, "relationship maintenance", "relationship attachment" in MSSTs relationship tool the property of their relationship with the results derived value, at the same time by means of Kano two-dimensional quality mode analysis confirm the quality classification of each variable, and then put forward various stages of relationships it is important attributes and psychological perception of content, as each stage of the consumer food and beverage industry MSSTs goods and services provided by the content providing companies with reference to the design of goods and services , and to develop products and advertising strategies of reference .

In this study Objective chain and Kano two-dimensional quality analysis method combines two modes of analysis, with the characteristics of each stage of the relationship marketing and so on, export consumer spending deeper feelings, to provide planning and design-related service providers MSSTs time content analysis services of reference.

Analysis of this study should be applied to the various service sectors of the fixed service field, ie such as airports, tourism and other service industries, by this research framework and analysis methods for understanding consumer between consumers and businesses through MSSTs the use of a clear relationship to each other, and to maintain the state of attachment , in order to develop the appropriate services and marketing strategies, while amplifying the industry's service areas.

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# Post-Contract Outsourcing Relationship Management Capability and Outsourcing Performance: Plant Level Analysis

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## ABSTRACT

IT outsourcing has become one of the biggest business trends and highest IT growth sectors. The vast magnitude of financial resources invested in IT outsourcing every year has raised outsourcing firms' concerns regarding their capability to manage relationships with outsourcees in a way that realizes the promised benefits of outsourcing and more. Adopting the resource-based view as a theoretical lens, the purpose of this study is twofold. First, we intend to explore the structure of an under-developed construct, namely post-contract outsourcing relationship management capability (ORMC) and its content using the Delphi method. Secondly, a case study involving two plants in a large corporation is documented in an attempt to test the relationship between ORMC and outsourcing performance. The findings of the Delphi survey show that ORMC is a multifaceted construct that consists of three dimensions: information systems management capability, interpersonal relationship management capability, and outsourcing contract management capability. Preliminary evidence obtained from the case presented in this study also indicates that ORMC has a positive relationship with outsourcing performance. The findings supplement the prevalent thinking in the area that focuses on the ex-ante and more-or-less ignores the ex-post outsourcing stages. Implications, limitations, and recommendations for future research are also discussed.

## KEYWORDS

Outsourcing relationship management; outsourcing relationship management capability; outsourcing performance.

## INTRODUCTION

IT outsourcing has become one of the biggest business trends and highest IT growth sectors. Global outsourcing market size has grown from US\$45.6 billion in 2000 to US\$76.9 billion in 2016 (Statista, 2017) with percentage of outsourcing spending to organizations' IT budgets remaining constant throughout the years (Beacon, 2015). While outsourcing has remained a substantial cost for organizations, in recent years more and more companies are looking to approach outsourcing in innovative ways (Deloitte, 2016). However, for many organizations, the significant potential benefits of outsourcing prove to be elusive in practice. Numerous sources have mentioned the large number of outsourcing deals failing to deliver the expected value (Craig and Willmott, 2005; Lacity and Willcocks, 2015; Landis, Mishra, and Porrello, 2005; Handley, 2012; Robinson et al., 2008). A 2005 Deloitte study also reported that 70% of the companies surveyed had a negative experience with outsourcing (Deloitte, 2005). The disappointing results have raised concerns for outsourcing firms regarding their relationship management with the outsourcees (Enlow and Ertel, 2006; Handley, 2012; Lacity et al., 2015).

IT outsourcing involves a multi-stage process that consists a sequence of corporate activities regarding supplier evaluation, contract negotiation, and contract execution. Since outsourcing involves a buyer-provider dyadic relationship, relationship management is thus critical to the success of outsourcing. Outsourcing relationship management models the development and evolution of the client-supplier working relationships in the entire outsourcing process in the hopes to identify the best practices that can reduce costs, contain risks, and avoid pitfalls in IT outsourcing. In practice, the outsourcing firms need to have various sets of outsourcing management capabilities at different outsourcing stages to evaluate and implement these practices and accurately measure the outsourcing performance both before the contract is signed and throughout the process. In this study, we intend to explore the capabilities of the client company to manage a relationship with external IT service suppliers, with particular focus on the post-contract stage of the outsourcing lifecycle. We refer to this construct as outsourcing relationship management capability (ORMC).

The existing literature reveals that a resource-based view (RBV) was commonly used to address the significance of ORMC to IT outsourcing performance (Ensslin et al., 2015; Grover and Teng, 1993; Lacity and Willcocks, 2015; Lee and Kim, 1999; Leslie and David, 2006). The results indicate that it is essential for organizations to develop adequate IS human resources to achieve designated outsourcing objectives. Kishore et al. (2003) asserted that even though focal firms prudently screened and selected qualified outsourcing providers and crafted a perfect contract, the potential benefits associated with outsourcing may not necessarily be realized. However, cases have also shown that firms capable of managing the relationships with their outsourcing vendors can achieve substantial cost savings and service improvements (Kern and Willcocks, 2002, Lacity, Khan, and Yan, 2016). Additional cases suggest that after IT services are outsourced, a good relationship management capability enables focal firms to evaluate the performance of suppliers and monitor the level

of services that the outsourcing supplier should provide to meet the information needs of the client firms. Consequently, ORMC may enable a firm to reduce outsourcing risk (Lacity and Hirschheim, 1993; Lacity and Willcocks, 1995; Lacity and Willcocks, 2015; Leslie and David, 2006; Lowell, 1992; Sobinska and Willcocks, 2016).

Although extant studies have pointed out the significance of ORMC, few studies have explored its structure and specified its substance. In addition, though the existing studies indicate the significance of ORMC on achieving superior outsourcing performance, they are largely anecdotal, and the research context is mostly at the organizational level. There is a modicum of empirical studies that test the relationship at the local level. To fill this gap, this study will examine the selective outsourcing of an IT function—IT maintenance and support, which is the most frequently outsourced service (Ahmed, 2006). The purpose of this study is twofold: first, we intend to explore both the structure and content of the post-contract ORMC using Delphi method. Second, a case-based research is conducted on two plants to test the relationship between ORMC and outsourcing performance.

The remainder of this study is organized as follows. In the next section, we review the extant literature related to the subjects of ORMC and outsourcing performance. Subsequent sections describe the Delphi technique, including its procedures and results. Next, the case study and its results are presented, followed by the discussions of our findings. This paper concludes with the implications and limitations of this paper, as well as some directions for future research.

## LITERATURE REVIEW

### *Outsourcing Relationship Management Capability*

Much of the past research on ORMC has focused on the importance of client-supplier relationship management (Cross, 1995; Ensslin et al., 2015; Handley, 2012; Kern and Blois, 2002; Kern and Willcocks, 2000; Lacity, Khan, and Yan, 2016; Lacity and Willcocks, 2001; Lee, Miranda, and Kim, 2004) and suggested that ORMC is a critical factor in successful IT outsourcing arrangements (Cullen, Seddon, and Willcocks, 2005; Davis, 1996; Fitzgerald and Willcocks, 1994; Johnson, 1997; Klepper, 1994, 1995; Lacity and Hirschheim, 1993; Lacity and Willcocks, 2001; McFarlan and Nolan, 1995; Mylott, 1995; Poppo and Zenger, 2002; Sobinska and Willcocks, 2016; Willcocks and Choi, 1995). However, research focusing on the construct of ORMC itself is limited to three relevant studies. Feeny and Willcocks (1998) first analyzed ORMC, and proposed a conceptual framework that depicts the core IS capabilities associated with managing outsourcing provider relationships. In their study, the construct of ORMC is made up of 4 sub-constructs: informed buying, contract facilitation, contract monitoring and vendor development. Informed buying refers to the capability of managing outsourcing strategies in a way that meet the business needs of focal firms. It entails analyzing the external outsourcing market and selecting the right IT providers. Contract facilitation is referred to as the capability to manage the process of contract arrangements, and provide mechanisms for conflict resolutions. The purpose is to reduce dissonance in regards to incomplete contracts that require continuous mutual adjustments by both parties. Contract monitoring indicates the capability to protect the client firm's contractual position and hold vendors accountable in terms of performance. This entails developing service level measures, payment structures, and performance standards. Vendor development refers to the capability of exploiting vendors' potential service value and resources. It involves developing client-supplier relationships through a futuristic-oriented stance that "looks beyond existing contractual arrangement to exploit long term potentials on a win-win basis".

Based on the above framework developed by Feeny and Willcocks (1998), Shi et al. (2005) explored the structure and specific substance of ORMC through interviews and a large-scale survey. Data analysis showed ORMC factored into three sub-constructs: informed buying, contract management, and interpersonal relationship management. The informed buying capability remains consistent with that proposed by Feeny and Willcocks (1998). Contract management capability refers to the ability to implement, monitor, and facilitate contractual arrangements. It is partially related to the concepts of contract facilitation and contract monitoring mentioned by Feeny and Willcocks (1998). The relationship management capability refers to the ability of the outsourcer to increase mutual understanding and trust with outsourcing providers through conflict resolution mechanisms. This construct is similar to Feeny and Willcocks' (1998) concept of vendor development.

Lastly, Goo et al. (2009) develop a comprehensive service level agreement (SLA) structure in IT outsourcing arrangements to examine the relationship between formal contracts and relational governance in IT outsourcing. They found that three characteristics of formal contracts – foundation, change, and governance – contribute fairly to the development of relational norms, harmonious conflict resolution, and mutual dependence of IT outsourcing relational governance. However, their study also suggests that change characteristics in contract can instead dampen trust and commitment in IT outsourcing relationship.

The above studies significantly contributed to our understanding of the construct of ORMC. However, the three frameworks attempted to provide an overarching scheme that covers the entire outsourcing lifecycle, and therefore are not specifically targeted on the phase immediately following the signing of the outsourcing contract. For example, the informed buying construct depicts capabilities that are required in the pre-contract stage, while contract facilitation and SLA structure focuses on the process of contract arrangement. Although the "contract monitoring" and "vendor development" of Feeny and Willcocks (1998), as well as Shi et al's (2005) contract management capability and relationship management capability are capabilities associated with the post-contract stage, it is uncertain that they

represent an exhaustive list. Meanwhile, Goo et al.'s (2009) relational governance relates more to the expected state in IT outsourcing relationship following the contract rather than organizational capabilities necessary to successfully manage IT outsourcing post-contract. Therefore, this study employs the Delphi method to inspect the specific structure and content of ORMC in the post-contract stage of the outsourcing process.

Furthermore, the level of analysis in Feeny and Willcocks (1998), Shi et al. (2005), and Goo et al.'s (2009) focus largely on the organizational level. Thus, the primary subjects are the managers who administer high level outsourcing tasks such as the outsourcing strategy, contract planning, and client-supplier strategic relationship development. However, the subjects for this study are specifically targeted as IS personnel at the operational level. The ability of IS operatives to manage relationships with suppliers is particularly essential during the post-contract stage of outsourcing because they are the employees who actually discuss terms with vendors and execute the contracts. We believe that line IS operatives with strong ORMC are critical to the effective implementation of outsourcing programs as any IS problems can be solved on site without a need to consult people higher on the management authority line. Reporting dissonance and conflicts to higher management may result in a missed opportunity to solve problems as they occur, which also affects the effectiveness of the outsourcing performance.

### *Outsourcing performance*

Since outsourcing performance is a broad concept, this study pays focus particularly on performance measurements that can be reflected at the plant level. In doing so, three dimensions of outsourcing performance are considered: cost reduction (Grover et al., 1996; Insinga and Werle, 2000; Kuo, 1996; Lee, 2001; Quélin and Duhamel, 2003; Takac, 1994; Wang, 2002), systems availability (Blair et al., 1995; Carlson and McNurlin, 1989; Hakkenberg, 2011; Hubbard, 1993) and service timeliness (Domberger et al., 2000; Seddon, Cullen, and Willcocks, 2002). From an economic standpoint, the first dimension is measured by the degree of expenditure decrease that client organizations pay to their suppliers each year. IT outsourcing cost reduction ideas have been widely employed in the MIS field (Gordon, 1994; Grover and Teng, 1993; Hubbard, 1993; Kuo, 1996; Lee and Kim, 1999; Lee et al., 2004; Minoli, 1995; Takac, 1994). Based on transaction cost theory, Wang (2002) investigated the relationship between vendor reputation, asset specificity, and perceived uncertainty and outsourcing performance where the IT outsourcing expenses cut was used as a surrogate for outsourcing performance. Likewise, when studying the influence of the degree of knowledge sharing among outsourcing organizations on outsourcing performance, Lee (2001) also regarded the IT outsourcing expense as the performance index to measure outsourcing results. In a study on the influence of the information system outsourcing degree on outsourcing effect, Grover et al. (1996) also used the outsourcing expense as the index to measure outsourcing effects.

The second outsourcing performance basis used in this study is IS availability (Blair et al., 1995; Carlson and McNurlin, 1989; Hubbard, 1993). Drawn from systems research, system availability refers to the percentage of total time that systems are actually operating while they should be operating (Lamberson and Wasserman, 2001). The other way of manifesting IS availability is through the minimization of system downtime (Domberger et al., 2000). Studies have suggested that the length of time that systems stay accessible and operational under the management of IT suppliers is a manifestation of outsourcing performance (Blair et al., 1995; Carlson and McNurlin, 1989; Hubbard, 1993; Kuo, 1996). Kuo (1996) suggested that outsourcing vendors were responsible for maintaining corporate information systems or increasing information service quality. Likewise, Marsour and Watson (1980) measured information system outsourcing performance based on the concept of effective use of information system. Finally, Hsu and Wu (2006) treated the degree of IS stability as an important criterion measuring outsourcing performance.

Research also proposes service timeliness, which refers to the time that elapses between outsourcing vendors being informed of a system problem to the time when that problem is solved, as a measurement of IS outsourcing performance (Domberger et al., 2000; Seddon, Cullen, and Willcocks, 2002). This measurement is based on the promptness with which suppliers respond to service requests and solve system problems. The longer outsourcing contractors take to react to systems problems, the worse the outsourcing performance becomes, and vice versa. The ability of outsourcing contractors to react to occasional or unexpected systems problems and to recover crashed systems affects the level of systems availability, which in turn has bearings on productivity and production cost.

## **THE DELPHI METHOD**

The Delphi technique is widely known for its utility in identifying issues and gathering opinions in areas that are still not well explored or lack empirical data (Linstone and Turoff, 2002; Uhl, 1990). In the MIS field, it has been widely used as a means for forecasting, issue identification, ranking, and concept/framework development (Bandara et al., 2005; Brancheau et al., 1987; Daniel and White, 2005; Doke and Swanson, 1995; Hayne and Pollard, 2000; Holsapple and Joshi, 2002; Schmidt et al., 2001). A review of the literature shows very few studies that focus on ORMC. Thus, the aim of this study is to identify the structure and substance of the underdeveloped construct ORMC. The research method for this study centered on Delphi surveys designed to elicit the opinions of a panel of experts through iterative controlled feedback. We adopted Linstone and Turoff's (1976) procedures to administer surveys.

*Expert selection*

The panel was selected by the author brainstorming likely relevant experts with rich experience in the domain of IS outsourcing. 22 experts participated in the entire Delphi process. The demographic information of the panelists is shown in Table 1, where we see that about 90% of the experts have more than one years of outsourcing experience, while 45% have more than 4 years of relevant work experience. The table also shows that over 50% of the experts have undertaken more than two outsourcing related projects. This information suggests that the participants are qualified to provide input for the inquiry.

*Table 1 Demographic Information*

<b>Demographic Information</b>	<b>Number of Participants</b>	<b>Percentage</b>
<b>Gender</b>		
Male	14	63.64%
Female	8	36.36%
<b>Age</b>		
Under 30	1	4.55%
30~40	21	95.45%
40~50	0	0.00%
50~60	0	0.00%
Over 60	0	0.00%
<b>Outsourcing experience</b>		
Less than 1 year	0	0.00%
1~3 years	10	45.45%
4~6 years	10	45.45%
7~9 years	2	9.09%
At least 10 years	0	0.00%
<b>Outsourcing Areas</b>		
Application software development (software or hardware)	13	28.26%
Systems maintenance or management	5	10.87%
User demand support service (Help Desk)	6	13.04%
Integrated system program development (software or hardware)	10	21.74%
Network service management (software or hardware)	8	17.39%
<b>Number of outsourcing related tasks</b>		
1	9	40.9%
2	5	22.7%
3	3	13.6%
4	4	18.2%
5	0	0.0%
6	0	0.0%
7	1	4.5%
8	0	0.0%

### *Questionnaire design and administration*

The Delphi survey essentially consists of a series of questionnaires. The first questionnaire asks participants to respond to open questions. The following questionnaire gives the panel feedback based on collective responses of the group, which provides the panelists with an opportunity to modify their previous answers in light of the newly shared information. The process continues in iteration until a consensus is reached (Okoli and Pawlowski, 2004; Schmidt et al., 2001). Prior to the delivery of the first survey, two non-panel IS experts were asked to evaluate the preliminary questionnaire to ensure that the questions were properly interpreted. They reported on any problems encountered while filling out the questionnaire, and it was modified accordingly.

The first questionnaire consisted of an open ended question concerning expert's views on the substance of outsourcing relationship management capability. 40 surveys were electronically delivered to participants, of which 23 (58%) were returned. After collection, two researchers worked together to examine the responses to the question. Irrelevant and duplicate responses were removed. The results yielded a list of 26 items. Two of the authors then worked independently to collate the responses and develop their own schemes that outline the structure of ORMC. Next, the two independently constructed schemes were likened and reconciled by the authors working in tandem. The resultant schema showed that three dimensions surfaced out of the 26 items. They were labeled as information systems management capability (ISMC), interpersonal relationship management capability (IRMC) and outsourcing contract management capability (OCMC) (see Table 2).

The second questionnaire was then sent to the 23 respondents who had replied to the first survey so as to gain more information via corrections, additions, or validations. Of those 23 surveys, 22 (95%) were returned. Panelists were asked to validate that the items had been correctly collated into groups that describe the constructs they were designated to define by rating each item on a 5-point Likert scale ranging from 1 ("extremely unsuitable") to 5 ("extremely suitable"). They were also given an opportunity to comment on any item of the questionnaire. The data were used for consensus analysis to measure the experts' degree of agreement on each particular item. A consensus analysis was performed using mean and quartile deviation (QD) derived from participants' ratings for each item. High means suggest that experts generally believe the item to rightly characterize the constructs it represents. QD was used to depict the degree of dispersion of a set of data. In this study, the smaller the QD, the higher the degree of consensus reached among the participants. A threshold of 4.0 and 0.5 are suggested as adequate for the mean and QD (Faherty, 1979; Buss, 2001). The results shown in Table 2 indicate that only 2 items (item 7 and item 8) had means and QDs below the recommended guideline. Therefore, these items were removed from the item list. In addition, the item "capable of planning information system architecture" (item 9 in Table 2) was a suggested addition to the list. This new item was included in the third questionnaire.

In the third survey, 23 questionnaires were again sent out, and 22 were returned. The third survey served to confirm the responses to the second survey. In addition to the consensus analysis, a response stability test was also performed. This test is used to assess the consistency of panelist responses to the same item in two surveys (Linstone and Turoff, 1976). In this study, response stability was operationalized as the ratio of the number of panelists whose responses to a particular item differed in one survey to the total number of respondents who responded to that item in the subsequent survey(s) (Buss, 2001; Holden and Wedman, 1993). It has been suggested that adequate response stability is demonstrated when less than 15% of the participants change their response to an item (Buss, 2001; Holden and Wedman, 1993; Linstone and Turoff, 2002). The Delphi survey was concluded as more than 70% of the items in the questionnaire were stable (Buss, 2001; Holden and Wedman, 1993; Okoli and Pawlowski, 2004; Siegel and Castellan, 1988). Table 2 exhibits the results of the consensus analysis and stability test. As shown, all items except item 8 displayed both high levels of agreement and stability. It also shows the structure and substance of ORMC resulting from the Delphi surveys. These results suggest that ORMC is composed of three dimensions: information systems management capability (ISMC), interpersonal relationship management capability (IRMC), and outsourcing contract management capability (OCMC). These sub-constructs are represented with 9, 7, and 7 associated descriptions, respectively.

### *Construct validity*

To test the content validity of ORMC resulting from the Delphi study, a Q sort procedure adapted from Moore and Benbasat (1991) was performed. A panel of judges consisting five IS researchers with an average of 6 year work experience participated. The item placement hit ratio was used to indicate how well the judges were able to sort the items into the constructs to which they were designated. The judges were asked to read carefully the construct definition and then placed each item into an appropriate construct. The hit ratio was calculated by dividing the number of items correctly placed by the total number of items placement. The overall item placement hit ratio of the sorting procedure was 98%, indicating that the items were largely being placed as they were intended to be.

Table 2 Delphi Survey Results: Construct Dimensions and Elements

Dimensions	Elements	Second Survey		Third Survey			Adopt
		Mean	QD	Mean	QD	Stability	
ISMC	Capable of identifying information system problems	4.64	0.5	4.5	0.5	9.09%	Yes
	Capable of diagnosing information system problems	4.68	0.5	4.55	0.5	9.09%	Yes
	Capable of detecting information system problems	4.45	0.5	4.64	0.5	13.64%	Yes
	Capable of describing information system problems	4.27	0.5	4.14	0.5	13.64%	Yes
	Capable of understanding information systems architectures	4.27	0.5	4.14	0.5	13.64%	Yes
	Capable of analyzing information systems architectures	4.27	0.5	4.36	0.5	4.55%	Yes
	Capable of constructing information systems architectures	<b>3.86</b>	<b>0.75</b>	---	--	---	No
	Capable of designing the functions of information systems	<b>3.95</b>	<b>1</b>	---	--	---	No
	Capable of planning an information systems architectures	---	---	<b>3.95</b>	<b>0</b>	---	No
	Capable of understanding the functions of information systems	4.64	0.5	4.59	0.5	4.55%	Yes
IRMC	Capable of analyzing the functions of information systems	4.5	0.5	4.36	0.5	9.09%	Yes
	Capable of utilizing the functions of information systems	4.55	0.5	4.55	0.5	0.00%	Yes
	Capable of dealing with provider problems	4.68	0.38	4.59	0.5	9.09%	Yes
	Capable of effectively communicating and negotiating with outsourcing providers	4.73	0.38	4.64	0.5	4.55%	Yes
	Capable of positively cooperating and interacting with outsourcing providers	4.5	0.5	4.55	0.5	4.55%	Yes
	Capable of establishing reciprocal relationships with outsourcing providers	4.45	0.5	4.59	0.5	13.64%	Yes
	Capable of solving dissonance with outsourcing providers	4.5	0.5	4.5	0.5	9.09%	Yes
	18. Capable of maintaining cooperation and interaction with outsourcing providers	4.55	0.5	4.59	0.5	4.55%	Yes
	19. Capable of maintaining reciprocal relationships with outsourcing providers	4.59	0.5	4.59	0.5	9.09%	Yes
	20. Capable of understanding outsourcing contract regulations	4.32	0.5	4.45	0.5	13.64%	Yes
OCMC	21. Capable of analyzing outsourcing contract regulations	4.23	0.5	4.41	0.5	13.64%	Yes
	22. Capable of judging regulations of outsourcing contracts	4.27	0.5	4.23	0.5	13.64%	Yes
	23. Capable of leading outsourcing implementation processes in regards to the contract	4.23	0.5	4.23	0.5	0.00%	Yes
	24. Capable of judging the effectiveness of outsourcing implementation in regards to the contract	4.23	0.5	4.45	0.5	13.64%	Yes
	25. Capable of controlling outsourcing implementation progress in regards to the contract	4.5	0.5	4.27	0.5	13.64%	Yes
	26. Capable of assessing outsourcing performance in regards to the contract	4.27	0.5	4.32	0.5	4.55%	Yes

*Delphi Survey Results*

As Table 2 shown, the results of the Delphi study suggest that ORMC is composed of three dimensions: information systems management capability (ISMC), interpersonal relationship management capability (IRMC), and outsourcing contract management capability (OCMC). ISMC represents the extent to which the local IS operatives can apply the IT skills to determine and gauge information systems problems. The results indicate that when a firm outsources its IT

services, IS operatives of the focal organization do not have to know how to plan, construct, or design information systems as traditional wisdom suggests but need to detect IS problems prior to system breakdowns. ISMC represents the ability to diagnose where the systems go wrong and how problems occur. This kind of technical know-how allows IS personnel to analyze the scope and depth of the problems and provide solution alternatives that are associated with information systems.

IRMC refers to the extent to which the IS operatives can work and collaborate with outsourcing vendors to achieve goals expected due to the use of outsourcing initiatives. It allows social exchanges to occur between the IS operatives of the outsourcing firm and their counterparts, from which closer ties can be developed and mutual trust and respect established. The reciprocal relationship cultivates a sense of bonding, so that both parties can effectively communicate and information can be freely exchanged. This relationship building capability facilitates understanding on the part of suppliers regarding who and what their counterparts are as well as their future plans.

OCMC refers to the extent to which IS personnel understand the outsourcing contractual terms, provisions, and their application. It reflects the ability of the IS operatives to monitor and evaluate the performance of suppliers. With this knowledge and know-how, the local IS staff can effectively judge if the suppliers provide the level of service regulated in the contract, and thereby assess vendor service quality.

## CASE STUDY DESIGN

We choose a case study methodology to explore our second research question: the impact of ORMC on outsourcing performance. Case research is particularly useful for the exploration, classification and hypothesis development stages of knowledge accrual (Benbasat et al., 1987; Bonoma, 1985; Yin, 1984; Dubé and Paré, 2003). This study is exploratory in the sense that few studies have provided a theoretical lens to the development of precise hypotheses concerning the relationships between ORMC and outsourcing performance. As such, we presented and analyzed case data in an attempt to test the positive relationship between ORMC and outsourcing performance and provide insights on how this relationship unfolds.

In this study, two cases were carefully selected to represent the variation of ORMC and outsourcing performance. In this way, the positive relationship between ORMC and outsourcing performance is revealed in that strong ORMC should be present in the more successful case and less evident in the less successful case. Thus, the multiple cases serve as “replication” logic for our results (Yin, 2003)

A large Taiwan-based public company (Company X) was used in the case study. Company X is a world leading TFT-LCD manufacturing cooperation with over 4500 employees worldwide. It entered into an outsourcing venture with two underlying objectives: to save money and become more efficient in terms of operations. For several years, Company X has outsourced its IS maintenance services to a large international outsourcing provider. The annual contract price is substantially fixed, but also permits limited adjustments for fluctuations in service level and the volume of maintenance activity. The exchange of services is carefully listed in the service level agreement.

Two LCD plants (FAB1 and FAB2) that belong to Company X were used as the units of analysis for this case study. This design allowed us not only to place the two plants on the same scale in terms of comparing their ORMC and outsourcing performance but also to effectively control important factors such as organization size, culture, and outsourcing providers that may have confounding effects on the ORMC-outsourcing performance relationships. Controlling these confounding factors enhances the reliability and validity of the case study results (Yin, 2003).

To further ensure the reliability and validity of research outcomes, this study used multiple sources of evidence. First, a senior IT manager (Director A) served as the key informant. Director A was selected on the grounds that he was the only senior manager directly supervising the IS operation of FAB1 and FAB2. Therefore, we believe that Director A not only possesses substantial knowledge regarding the inquiry under investigation, but also can provide objective and unbiased assessments regarding the two plants' ORMC and outsourcing performance. To cross reference Director A's observations, we also interviewed one IT manager from FAB1 and FAB2 (Manager B and Manager C) to gain supplementary remarks that helped shore up the reliability and validity of our case results.

Data for this study were collected through three semi-structured on-site interviews with Director A and two plant managers. Each interview was separately conducted and took 70 to 90 minutes. The interviewer used a set of questions guiding the discussion. In the first interview, Director A was asked to assess the ORMC of both FAB1 and FAB2, as well as to provide insights on the relationships of ORMC and outsourcing performance. Particularly, Director A was asked to provide instances to illustrate his comments when available. The same interview, using identical data collection protocols, conducted the remaining two interviews where the two plant managers make comments separately and independently based on their own judgments. At the completion of each session, the interviewer carefully read the transcripts to ensure their accuracy and completeness. All interviews were tape-recorded and then transcribed for subsequent analysis.

In examining the relationship between ORMC and outsourcing performance, we collected hard data on the outsourcing performance from Company X's log systems in addition to Director A's assessments. These performance index include IS outsourcing cost reduction, IS availability, and vendor service timeliness. Past studies tended to state information

system outsourcing results based on the degree of expense reduction. However, total expense cuts tend to vary due to the volume of information system outsourcing. The amount of outsourcing expense alone will not allow us to compare outsourcing performance of different units. To avoid this problem, outsourcing expense decreases in this study were based on the average cost of each outsourced system unit, calculated by dividing the total outsourcing expense by the number of units outsourced. Further, the average system unit cost reduction was based on the difference of unit average costs of a certain year compared to the costs for the previous year. Also, IS availability referred to the percentage of actual operational hours and total expected operational hours of information system in the year. Finally, service timeliness was the total time spent on the system problems by the outsourcing vendors, beginning with when they were informed and lasting until the point when all system problems were solved.

## CASE ANALYSIS

### ORMC and outsourcing cost reductions

Figure 1 displays the average cost reduction rate per information system figures for FAB1 and FAB2 from 2004 to 2007. From 2005 to 2007, the average costs for each system unit in FAB1 were reduced by 3.06%, 2.24% and 13.44% respectively. FAB1 cost reduction rates during those three years were 1.7, 3.2 and 2.8 times higher than those of FAB 2, which totaled 1.79%, 0.70% and 4.76%.

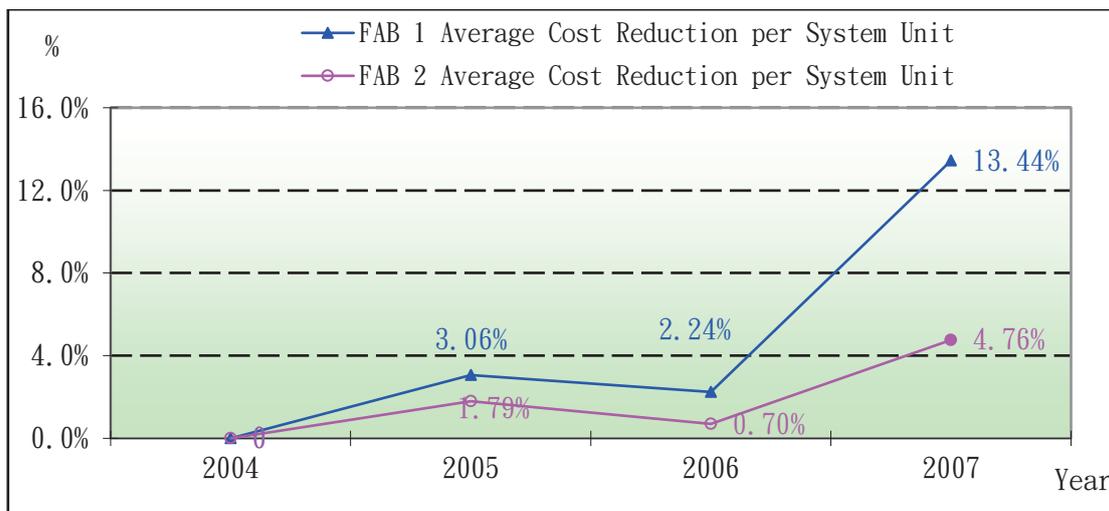


Figure 1 Average Cost Reduction per System Unit  
Source: Provided by Company X

Director A asserted that FAB1’s higher level of ORMC contributed to its superior performance in terms of reducing system outsourcing costs. First, Director A observed that FAB1 had strong ISMC that enabled it to effectively detect and analyze IS problems. This in turn effectively controlled supplier behavior and curbed outsourcing expense increases. Director A used the change of network facilities in 2006 as an example. He said:

“In 2006, FAB1 needed to change its network systems. FAB1 asked the outsourcing vendor to quote a price to complete the project based on the estimated time and manpower required. When the vendor submitted the information, the IS guys in FAB1 knew right away that they were being overcharged. They replied with various sound arguments and eventually cut the cost in half.”

Manager B agreed with Director A’s observations and stated:

“My people are experienced and skilled; they knew how long it would take to install the systems and how many people were required to do the job. As such, they were less likely to be manipulated by the vendor. Because of this, we saved a lot of money when dealing with the service provider.”

In addition, Director A contended that high IRMC was another reason that FAB1 could decrease outsourcing costs to a far greater degree than FAB2. He used a case concerning a systems upgrade as an example. In 2005, FAB1’s network systems experienced a stability problem in that the connection repeatedly turned off and on. In order to solve the problem, FAB1 decided to replace them with new systems. Since the IS operatives in FAB1 had established reciprocal relationships with the vendor, the vendor fully supported the project and did whatever was necessary to meet the go-live schedule and budget that FAB1 requested. The vendor even refused to bill extra for things that were not clearly defined in the contract.

On the contrary, Director A asserted that because FAB2 was unable to work with the vendor, their outsourcing costs continued to escalate. The lack of IRMC was partly due to a high turnover rate of senior information staff, which inhibited FAB2 from maintaining its established relationship with the vendor. Also, FAB2 IS operatives were unable

to effectively communicate with the vendor to achieve mutual understanding, which inhibited the development of a spirit of trust and partnership. Consequently, FAB2 experienced significant difficulties working with its counterpart.

Manager C agreed with Director A's observations and added:

"Our turnover rate was high, and the skills and relationship built by our senior staff was not passed on to their successors. The new comers did not communicate well with their counterparts, which often led to serious quarrels. The vendor became distant and indolent to our requests. This did not help us in our attempts to thwart unplanned systems interruptions, so when a system did have problems, the vendor seldom worked diligently to find ways to solve them. Everything went according to the contract: anything not listed in the contract was our own problem. By contrast, I think FAB1 worked a lot better than we did. We had the same supplier, but FAB1 often receive better service than we did. The supplier even provided them with services that were not clearly stated in the contract."

In the interview, Manager C gave a further example:

"In 2005, the disk array of an information system crashed. We filed a service request to the vendor asking for recovery of the systems. Since this was urgent, we did not follow the coded procedure to file the request. My people reported that the vendor did not respond to our request immediately, and asked us to file the application by the book. Since we were under extreme pressure while trying to bring the system back on, my people and their counterparts had numerous serious disputes. My people were furious about the way their counterparts dealt with the event. They told me that the vendor was merely following the contract and did not seem to care about what had happened or how we felt. Eventually, the systems were brought back on, but it took longer than we had expected. Thus, we fell behind our production schedule, and we were forced to pay extra fees to the vendor for overtime work. They (the counterparts) did everything by the contract and we could do nothing about it."

Moreover, both Director A and Manager B indicated that the information personnel of FAB1 had strong OCMC. They knew about the content of the contract. Director A and Manager B argued that this was another reason that FAB1 outperformed FAB2 in terms of systems cost reduction: understanding the content of the contract allowed FAB1 to protect its contractual positions when disputes and disagreement arose. It was able to effectively judge if the supplier was providing the level of service that was contracted, and prevented the vendor from shirking contracted jobs or overcharging for them. In addition, FAB1 was able to control and assess vendor service quality based on the contract. When the vendor failed to fulfill all contracted responsibilities, the IS operatives weighed the impact and set the level of penalty for the vendor.

Manager C agreed with Director A's observation. He indicated that the IS staff in FAB2 did not understand the content of the contract as clearly as those in FAB1. Therefore, FAB2 was incapable of protecting its contractual positions by effectively evaluating the vendor service provisions and quality. Nor could it prevent the vendor from overcharging. Because of low OCMC, FAB2 seemed unable to control the maneuvering tactics the vendor employed to avoid its contractual duties.

#### *ORMC and system availability*

Figure 2 demonstrates the system availability rates of FAB1 and FAB2 from 2004 to 2007. It is apparent that the rates of system availabilities of FAB1 were 99.49%, 99.83%, 99.9% and 99.92% respectively, and all on the rise. By contrast, those of FAB2 were 99.63%, 99.66%, 98.16% and 96.09%, thus dropping every year. The systems availability gap between FAB1 and FAB2 widens when the availability rates are exhibited as system downtime. In 2005 and 2006 FAB2's total systems downtime was 2.0, which was 18.4 times higher than that of FAB1; in 2007, the difference rose to 48.9 times. The data clearly shows that FAB1's systems availability was significantly superior to that of FAB2, and that the gap increased over these years.

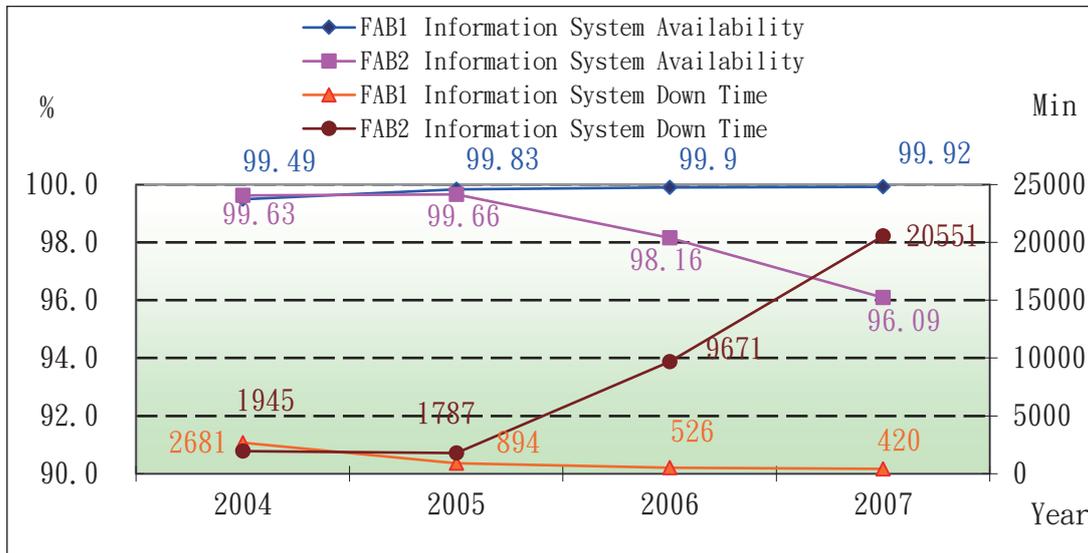


Figure 2 Systems Availability  
Source: Provided by Company X

Director A argued that the main reason for this gap growth was that FAB1 had higher ORMC than FAB2. With regards to ISMC, when systems experienced malfunctions or other problems, IS operatives in FAB1 effectively diagnosed the sources of the problems and gauged how serious they were. With strong IT technical skills and knowledge, the IS operatives could provide technical specs that radically reduced the time and effort necessary for their counterparts to analyze and identify systems problems, and subsequently less time was spent to get systems back up and functioning. Thus, technical skills and knowledge enhanced system availability by minimizing system downtime. He recalled that in 2004, FAB1 IS operatives found various programming bugs in a system that made the system unable to fully perform the functions it was designated to support. The FAB1 technicians made an in-depth inspection of the architecture and parameters of the system. As soon as their counterparts arrived, FAB1 IS personnel briefed the newcomers on what they had found. The vendor counterparts started to solve the problems without having to repeat the work completed by the FAB1 technicians. After a few hours, the ruptured system went live again. The vendor indicated that this could not have happened had its counterparts not provided referenced information on the system anomaly. FAB2 experienced a similar case in 2005. However, the results were totally different. IS operatives in FAB2 could not detect the cause of the abnormality and thus had to rely completely on the vendor. The vendor took many hours to pinpoint the problems that had caused a disruption in the system. Then another a few hours were spent solving the problem. It took almost twice as much as FAB1 spent on the same event.

Manager C agreed with A's comments and said:

“When the computer systems were down, all we could do was wait for the vendor. My people were not able to find where or what the problems originated from, and thus were totally reliant on the vendor's analysis and judgments. Also, precious time was wasted while waiting for the vendor's reports and resolution plan. In one instance, our men even came to a wrong conclusion regarding the cause of one system failure. The vendor took extra time to discover the real problem and it ended up seriously affecting the system availability.”

Further, Director A and Manager B both stated that the positive relationship between FAB1 and the outsourcing vendors contributed to their high systems availability rate. They explained that a sense of trust allowed FAB1 to effectively exploit and explore the resources of its counterpart. Due to the relationship, the vendor was willing to share its expertise and practical experience. Both in formal and informal settings, the two parties would openly discuss the systems facing potential operation problems. On many occasions, systems did not go down because precautions actions based on vendor's advice were well implemented. These exchanges in system related information were valuable in terms of avoiding unexpected systems interruptions. In contrast, IS operatives in FAB2 did not build up good relationships with their counterpart, such that trust and cooperative spirit were missing when the two parties worked together. Miscommunications and quarrels often took place. When disagreements arose, FAB2's IS staff seemed unable to resolve them. As a result, the vendor became extremely aloof and only responded to direct requests. When the vendor perceived that a particular system might be experiencing a problem, it never informed FAB2.

Director A stated:

“In 2006, an important server crashed. The technicians working for the vendor knew a few months previously that this was likely to occur at some point, but they did not tell FAB2. Further, when FAB2 told its counterparts that the server was down, they did not respond immediately; instead, they stated that they would react when a request for service was filed by the book. Two issues became apparent. First, this event could have been prevented if they had advised up to

take precautions. Additionally, it took at least 30 minutes for us to go through the formal request process. This certainly affected our rate of systems availability.”

Manager C recalled that the FAB2 IS operatives tended to exploit their counterparts by asking them to do jobs not arranged for in the contract. The exploitative maneuvers often led to destructive disagreements and quarrels, which further sent the mutual relationship into a downward spiral. Finally, the vendor declined to actively find ways to help. Since the two parties did not communicate well, systems problems usually could not be solved quickly, which in turn brought down the systems availability rate.

With regard to contract management, Director A and Manager B both indicated that in-depth understanding of the contract allows IS operatives to more effectively monitor vendor behavior. Since IS operatives in FAB1 clearly understood the requirements stated in the contract, they were in a position to ensure that outsourcing vendors were not adopting outdated techniques or system parts that would affect the system availability rate. Director A recalled:

“In 2005, a PC server fan in FAB1 crashed. The vendors replaced it with a generic product, rather than the brand specified in the contract. Fortunately, the IS operatives discovered this and required the vendors to substitute it with the branded product specifically listed in the contract. The generic brand fan was later reported to have an inferior running time as compared to the branded one. Thus, system downtime was likely averted due to this seemingly trivial action.”

On the contrary, Director A asserted that because IS operatives in FAB2 did not fully understand the content of contract, they found themselves unable to hold outsourcing vendors to the types of products and degrees of service in the contract, and were also unable to assess vendor service performance. Director A stated:

“In 2006, a major FAB2 database crashed because of a faulty network card. Since the cause of the problem was unclear, the contract vendors had to collect data for analysis and provide a detailed report on the cause as well as directives to avoid a reoccurrence. After the database was reconnected, the vendor never submitted the report as required, and FAB2 did not even know to ask for it. Three months later the same problem reoccurred. We later understood that if the FAB2 IS operatives had read that report, the database would not have gone down again. This event seriously affected the overall systems availability performance for that year.”

*ORMC and service timeliness*

Figure 3 demonstrates the time that vendors spent recovering failed systems for FAB1 and FAB from 2004 to 2007. Over the specified period, the total problem solving time for FAB2 was 957, 858, 2655 and 3390 minutes, respectively. By contrast, the counterparts for FAB1 used only 590, 415, 385 and 308 minutes. In 2004 and 2005, FAB2 took 1.62 and 2.07 more time for system recovery than FAB1 did. However, in 2006 and 2007, the ratios reached 6.90 and 11.01 times. In short, FAB1 waited significantly less time to bring their failed systems back on than FAB2 did, and especially worrying is that the gap actually rapidly increased over this period.

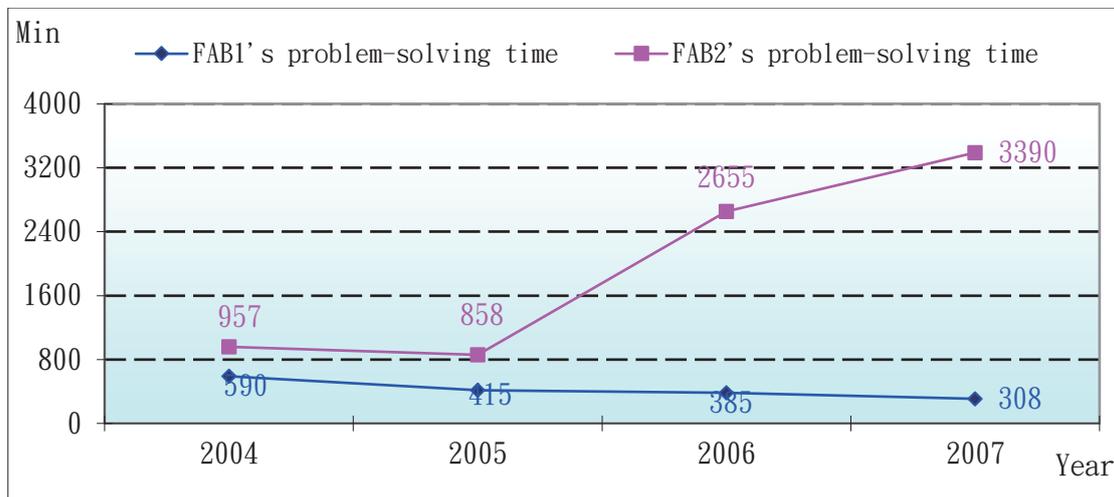


Figure 3 Service Timeliness  
Source: Provided by Company X

Director A argued that the high ISMC displayed by FAB1 enabled them to decrease the time vendors required to fix systems problems. He further observed that when systems were down, FAB1 IS operatives displayed the ability to correctly identify problems. This information was extremely critical for the problem-solving processes, as it allowed the vendor to direct its efforts towards searching for appropriate resolutions that would bring the systems back online sooner. Manager B agreed with Director A’s comments and used the following case as an illustration:

“In 2006, one of our core information systems went down. Our IS operatives immediately found that the cause was the memory card on the motherboard, and duly informed their counterparts. Thus, IS operative IT skills and knowledge significantly sped up the system recovery process, because correct information regarding possible causes for the system glitches was available when the counterparts arrived. This helped the vendor specialists know exactly what kind of situation they were dealing with and how to resolve it. I firmly believe that it would have taken much more time to get the system back up and running if our men had not been able to identify the cause of the problem.”

Director A contended that FAB2 did not have sufficient technical capabilities to detect and analyze system problems. Director A recalled that at the beginning of 2007, FAB2’s manufacturing execution system was not functioning properly. The IS department misjudged the cause and that mistaken analysis misled its outsourcers. The vendor in turn used up many hours to find the real problem, increasing the total time needed to recover the troubled systems.

Director A indicated that FAB2 fell short of adequate IRMC. Those IS operatives and their counterparts had a hard time building up a spirit of cooperation and reciprocal respect on which steadfast working relationships are based. Consequently, when receiving requests from FAB2, the vendor tended to be restrictive in terms of the services required by the contract, and declined to offer services outside of the contract. Furthermore, they showed indifference to the system problems and required FAB2 to go through all formal application procedures when FAB2 issued requests. This significantly increased the time required to get the systems back online.

In addition, Director A emphasized that OCMC plays an important role in allowing vendors to provide speedy services. FAB1 was capable of establishing reciprocal respect and trust with its outsourcing counterparts, who in turn tended to be cooperative and do whatever was necessary to get the systems up and running as soon as possible. Director A offered this example:

“Our systems have to undergo an annual maintenance initiative each year, and it is extremely important to get the job done on schedule. If the maintenance operations take up extra time, plant production schedules will be significantly affected, leading to enormous production losses. IS operatives in FAB1 have established strong associations with their counterparts, and the vendor does its best to get the job done as soon as possible. In fact, most of the time systems come back up ahead of the maintenance schedule.”

Manager B was in agreement with Director A’s observations and stated:

“My people know about the contract. Their counterparts also know that they have very little room to maneuver. The vendor is usually quick to respond to our system requirements and works hard to bring the system back up on time, because penalties can come into effect if they do not meet the requirements stated in the contract. Every year as the vendor performs the annual systems maintenance assignment, my people closely monitor and evaluate if the vendor is keeping up with the schedule and deadlines. Several times, upon observing that the working speed was falling short of the expected performance, my people would directly ask the vendor to increase its workforce so as to keep up with the planned maintenance schedule. Over the years, my people have become capable of controlling the system maintenance process, and in the end, the systems are always running on time.”

Manager C also indicated his support of Director A’s observation that FAB2’s IS personnel fell short in terms of specific knowledge regarding the contract, which led to the debasement of service efficiency. This was partly because the IS operatives were unable to defend their positions by asking their counterparts to observe what was required in the contract. Director A said:

“At the beginning of this year (2007), a major database went down. The vendor took more time to bring the system back online than was allowed for in the contract. However, FAB2’s IS operatives at that time did not know that the time spent to solve the problem was over the limit. Had the IS operatives known the regulations contained in the contract, they could have forcefully demanded that the vendor get the job done within the stipulated limit, and the system would likely have been back to normal sooner than it was.”

## **RESEARCH FINDINGS**

The Delphi survey shows a tripartite scheme for ORMC: ISMC, IRMC, and OCMC. ISMC refers to the technical skills and knowledge that can identify and determine system problems. IRMC relates to the abilities to effectively communicate and negotiate, so as to develop and maintain strong associations characterized with reciprocal trust and a spirit of partnership with outsourcing suppliers. OCMC reflects the extent to which the local IS operatives understand the outsourcing contract, so that they can monitor vendor behavior and evaluate service performance. The results confirm what has been advocated in the past studies: it is important for outsourcers to have the capability to nourish reciprocal relationships with contractors and monitor their performance in the post-contract stage of outsourcing. Unlike other outsourcing relationship management studies in which technical capabilities were not particularly highlighted, these findings suggest that even when firms outsource their information system services, they still need to display outstanding information technique management capabilities. These capabilities require the IT workers to have sufficient knowledge concerning the IS under their charge, and allow them to effectively detect systems problems prior to occurrence as well as analyze the cause and scope of systems problems after the systems are down.

This study specifically demonstrates that IS operatives at the local level need to have strong ORMC, for they are the line crews that actually work with vendors. Local IS operatives who are well equipped in terms of ORMC are essential to the effective execution of outsourcing contracts, as any IS problems can be solved on site without requiring the involvement of those higher along the line of management authority. Reporting dissonance and conflicts to higher management means problems are not being solved as they occur, and time is being wasted.

In addition, this research used two local production plants from the same firm as the units of analysis to probe into the relationship between ORMC and outsourcing performance. After analyzing data collected from multiple channels, we found that ORMC has positive impacts on outsourcing performance. The capability of applying IS techniques to the analysis of problems and the impact that they might have allows local IS personnel to also estimate the time and workforce required to solve the problems. Thus, it becomes less likely that outsourcing vendors find ways to take advantage of information asymmetry and thereby manipulate service fees. Eventually, strong ISMC can reduce outsourcing expenditures. Strong ISMC enables local IT personnel to provide insights regarding the problems that trouble the systems. These insights can save a tremendous amount of time, because vendors can simply focus on solutions rather than inspecting and diagnosing the systems. This significant problem-solving time trimming in turn enhances the system availability rate.

The cases also show that IRMC is positively associated with outsourcing performance. From the case study, we found that high IRMC leads to better communication and more trusting relationships with vendors. Reciprocal respect breeds a spirit of teamwork and inspires cooperation. In such an atmosphere, vendors become more willing to cooperate with the client firms and do whatever is necessary to support their needs. Evidence from this study reveals that when the local IS personnel have strong IRMC, their outsourcing counterparts tend to be more lenient in terms of the contract, and provide extra services as requested without additional charges. They also respond more promptly to outsourcee service requests, leading to less systems downtime. Moreover, outsourcing vendors become more willing to share their insights on potential problems that allow outsourcers to take preemptive initiatives and thereby fend off unexpected systems downfalls. Consequently, these preventative efforts often result in the improvement of systems availability. Finally, the findings from the case suggest that OCMC has a positive impact on outsourcing performance. Understanding the content of the outsourcing contract enables local IS operatives to assess if the level and scope of service that the vendor provides fulfills the requirements designated in the contract. In this way, the client organizations can safeguard its contractual positions against vendor maneuvers concerning contracted duties or extra service charges. In addition, a full comprehension of the contract empowers local IS operatives to: control and evaluate the promptness and quality of service that vendors perform, lead the outsourcing implementation process, and reduce outsourcing vendor problem solving time. These three together can combine to reduce information systems downtime, and further increase system availability.

## CONCLUSIONS

### *Implications and limitations*

This research study has several academic and practical implications. First, with regards to academic contributions, past studies largely focused on developing a conceptual framework of ORMC covering the entire outsourcing lifecycle. None specifically explored ORMC at the post-contract phase. The findings this study uncovers can enrich our understanding regarding the structure and elements of this important construct, and can serve as the basis for future research. In addition, the case study provides preliminary evidence that there is a positive relationship between ORMC and outsourcing performance at the local level. The findings suggest that to effectively enhance outsourcing performance, client organizations need to equip their subunit level IS personnel with adequate ORMC, as they are the ones charged with operating the information systems and interacting with the suppliers. Moreover, the findings contrast the prevalent thinking in the area, one that adopts a “contract” view that focuses on the ex-ante and more-or-less ignores the ex post and also indicate that outsourcing is more effective when ORMC persists throughout the life of the outsourcing process.

Several managerial implications follow from the results of this study. First, human resources are essential to the success of outsourcing. Rather than shifting the responsibility of IT services entirely to the outsourcees, the outsourcing firms need to possess substantial human resources to safeguard their interest and ensure that the expected outsourcing benefits are realized. Thus, outsourcing firms can use the results to assess if they possess ORMC, and to what degree. Results indicate that technical, relational, and contractual aspects of ORMC play equally important roles in influencing outsourcing effectiveness. Conventional wisdom hails technical proficiency in that reliable IT services depends on expert IT staff. However, good IT forces may be redefined in the context of outsourcing. Desired local IT forces should not only be technically capable, but also proficient in working with outsourcing vendors and executing outsourcing contracts. Furthermore, the ORMC content uncovered in this study can serve as a guideline for the design of education programs for high ORMC human resources. Particularly, in addition to technical training, outsourcing organizations also need to develop curriculum that train local IS operatives to effectively manage relationships with their outsourcing counterparts and to comprehend outsourcing contracts so as to effectively control vendor behaviors. Moreover, evidence

from the case indicates that high turnover rates inhibit the development of human resources with superior ORMC. This prompts the need for focal firms to developing rewarding systems to attract and keep experienced senior staff. The principal limitation of this study concerns the generalizability of the findings to other contexts. Our research specifically focuses on an exploration of the capabilities necessary for good relationships with providers in the post-contract stage. Thus, the results may not be applicable to other stages in the outsourcing lifecycle. Moreover, since we relied on a single informant approach in the case study, subjective perceptions might have influenced the preciseness of the data collected. In order to reduce the chance of bias, multiple methods of data collection were employed in an attempt at triangulation, which lends greater support to the conclusions. Thirdly, there may be potentially confounding influences of other factors that make logical deductions regarding the relationships between ORMC and outsourcing performance somewhat illusive. However, this study mitigates this shortcoming dictated in real-world case studies through the choice of a specific multi-case design. First, the sites were selected according to theoretical replication logic, in which the conditions of the cases lead to contrasting outcomes (Benbasat et al., 1987; Dubé and Paré, 2003; Yin, 1994). Secondly, the two sites are sub-units in a large LCD company. This design allows for controlled observations in which the potentially confounding influences of all other factors can be effectively removed. The goal was to minimize extraneous variables so that if significant factors were indeed found, there would be a high degree of confidence that only those factors caused the observed differences (Benbasat et al., 1987).

### *Recommendations for future research*

To the best of our knowledge, this is the first study to empirically examine the relationship between ORMC and outsourcing performance. Large sample cross-sectional studies in conjunction with longitudinal studies are called for to continue work in this area. The random selection of companies through a survey-based approach could allow for generalizations to be made across the population of industries or firms under consideration. Secondly, this research takes a resource-based view in examining the structure and elements that constitute the construct of ORMC. Future research can explore the source or the mechanisms from which the capabilities are bred.

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# Exploring Determinants and the Moderating Role of Shopping Orientation of Purchase Intention of Cross-Border Online Shopping

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## ABSTRACT

Cross-border online shopping has become a worldwide trend. Enterprises are interested in what makes consumer go cross-border online shopping. To assist enterprises to make better cross-border e-commerce marketing strategies and expand the area of e-commerce research, this study aims to explore and examine determinants that may affect purchase intention of consumers or not. This study proposes a new model for purchase intention of cross-border online shopping with 4 dimensions of deterministic factors. We examine what moderators significantly affect the relationships between deterministic factors and purchase intention. In addition, we collect data from at least 56 different cross-border e-commerce websites. "Price sensibility", "trust", "shopping convenience" and "price of product" are the most influential determinants in cross-border online shopping. Moderators do have moderating effects on the relationship between purchase intention and some specific constructs. Besides, we divided data into groups by types (B2C/C2C) of platforms, and found that the significant determinants differed by types of platforms. This study provides suggestions to enterprises for their cross-border e-commerce strategies because we found significant determinants of purchase intention. Since we also examined moderating effects, enterprises can improve their market segmentation according to those moderators.

**KEYWORDS:** Cross-border Online Shopping, Unified Theory of Acceptance and Use of Technology, Purchase Intention, Determinants of Purchase Intention

## INTRODUCTION

Online shopping has broken geographical barriers, and Internet continues to generate new business models. Due to the characteristics such as ubiquitous, and borderless, the trend of cross-border online shopping has been going upward. According to European Commission (2013), the amount of consumers who go cross-border online shopping has doubled from 2006 to 2013. Taobao (short for Taobao.com) annually launches 1111 sales festival (Singles' Day sales), which is a huge promotion campaign held on November 11th. In 2015, it was worth \$14.3bn, a 60% increase in such one year (Yan 2016). Cross-border online shopping is the international trade between enterprises or individuals from different nation, paid and completed via online platforms, and goods delivered by cross-border logistics. Although information exchange became faster thanks to the Internet, due to its nature of international trade, there are difficulties in communication, delivery and regulatory issues in the development of cross-border e-commerce. Purchasing brokers has always been popular by means of solving consumer's problems of buying goods that cannot be bought in his/her nation. Brokers help consumers by communicate with sellers, or "gathering" goods, which is similar with group buying, for multiple consumers to reduce the cost of international delivery. However, cross-border e-commerce is that enterprises deliver goods directly to where consumers are. To deal with communication barriers, enterprises adapt website localization for foreign markets with "local language" versions, so that they can approach more consumers. On the other hand, in order to deliver goods directly to consumers, enterprises look for cooperation with local third-party logistics. They may offer promotional shipping cost to attract consumers to come to them.

Since the complexity of cross-border online shopping is much higher than traditional domestic online shopping, understanding what added value can cross-border online shopping give to consumers is the critical success factor. If an enterprise intends to develop cross-border market, it is necessary to know the behavior and decision process to make good business strategy. Previous research related to cross-border online shopping mostly focus on auction websites purchasing brokers to study the behavioral intention of consumers. This paper focuses on independent purchase that consumer can complete by oneself instead of going through purchasing brokers or group buying.

Recently, cross-border online shopping shows vigorous growth, and it has become new engine for economic activities and international trade. The faster the nation develops cross-border online shopping, the higher its speed of increasing international trades is. Cross-border online shopping gradually becomes prevalent among consumers and they encounter with the topic recurrently in their daily life, this is hence an important trend for enterprises. It is a big challenge about how to attract more consumers to use. The importances of cross-border online shopping are concluded as follows:

Cross-border online shopping is the new trend of e-commerce: Purchasing agency has become an industry since a long time; even individual brokers can grow into well-established agent websites. However, under the huge waves of globalization, process of international trade becomes smoother, and consumers are more familiar with ways of cross-border online shopping. Except purchasing brokers, leading e-commerce enterprises such as Amazon and eBay has started their cross-border e-commerce. Individuals or small to medium size enterprises also try hard to seize the opportunity. The activeness of such business activity also shows that cross-border online shopping is a new trend in e-commerce.

The complexity of cross-border online shopping makes itself an important issue: in the past online shopping occurred domestically, so e-commerce studies were in the context of domestic online shopping. In order to develop cross-border e-commerce, enterprises

are exposed to new challenges of cash flow, logistics, and information flow at the same time. Previous success model may not cover all of the problems generated by cross-border trading obstacles.

The purpose why consumers go cross-border online shopping: previous e-commerce research tried to understand the reason why consumers adopt new shopping channel(s) from different perspectives. The development of cross-border online shopping is so rapid and prosperous, so that asking about what factors are behind such consumer behavior brings out new possibilities for research.

Thus, this study aims to look for determinants that impact purchase intention and behavior of consumers when they use cross-border online shopping service.

This study considers cross-border online shopping as a new technology service, so we adapted the perspective of technology acceptance to discuss determinants of consumer's purchase intention. Moreover, due to the complexity of context of cross-border online shopping, it is expected that a bigger model is necessary. In the past, the Unified Theory of Acceptance And Use of Technology (Venkatesh et al. 2003) is an interdisciplinary model that combined several behavioral and intention models. It was the basis spirit of our study and we explored more factors in other e-commerce issues to expand the dimension of determinants. In the process of cross-border online shopping, we can see four roles that interact with each other. They are consumer, service provider, others around one consumer, and environment such as institution. In order to clarify these four forces that affect consumer's choice and their interaction among each other, our research questions are around these four roles in cross-border online shopping.

This paper has the following objectives:

To explore factors about online consumers, and whether those factors impact purchase intention of cross-border online shopping.

To explore factors about cross-border online shopping platforms and whether those factors impact purchase intention of cross-border online shopping.

To explore factors about interpersonal interaction around consumers and whether those factors impact purchase intention of cross-border online shopping.

To explore factors about environment and institution and whether those factors impact purchase intention of cross-border online shopping.

To see whether different types of platforms relate to purchase intention of cross-border online shopping.

## LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

### *Related study of cross-border e-commerce*

Global sourcing has become important for manufacturing products at a lower cost. Products made overseas can be seen around our lives. Meanwhile, the rise of e-commerce significantly reduced the cost of information exchange. In previous marketing research, "outshopping" is the behavior of consumer that make retail purchase outside the area they live (LaForge, Reese, and Stanton 1984), and whether or not the consumer purchase outside the community is critical (Riecken & Yavas 1988). Broekemier and Burkink (2004) found that rural consumers utilized Internet to make efficient outshopping, and they intended to increase this behavior. Via Internet, consumers can now search and purchase cross-border products by just clicking. Besides enterprises, European Union(EU), which wants to create single digital market, focus on cross-border e-commerce, for instance. Gomez-Herrera et al. (2014) used gravity model to study the drivers and impediments for cross-border e-commerce in EU.

The exhibition of having preferences for particular shopping patterns by consumers is defined as "shopping orientation" in past research, but there are still no common standards for defining shopping orientation. Classification for shopping orientation is fragmented. However, Yen et al. (2008) indicates that shopping orientation can be roughly divided into two kinds: goal-focused and recreational shopping orientation. The former is that consumers aim to purchase goods or service by an efficient and easy way, under the least probability of being interrupted. The later is that consumers with high recreational shopping orientation go shopping for fun and enjoyment induced by the purchase process itself. These two kinds of consumers are differentiated by their behavior of either chasing for utilitarian or hedonic shopping value. To consumers, online shopping provides benefits including convenience, flexibility and reduction of cost and effort (Cho 2004). The capability of interaction and displaying vast variety of various goods let e-commerce generate more economic values and increase more shopping efficiency than traditional retailing.

### *Cross-border online shopping behavior under perspective of technology acceptance*

Theory of Reasoned Action (TRA) proposed by Fishbein and Ajzen (1975) assumed most behavior of an individual is able to take actions on his/her own will, and behavioral intention has impact on taking real action. Behavioral intention is affected by individual's attitude toward the action and Subjective Norm. Ajzen (1985) added Perceived Behavior Control as a new determinant of TRA model, and proposed Theory of Planned Behavior (TPB). These two models have been widely applied to understand acceptance behavior of an individual. Technology Acceptance Model (TAM), focused on information system usage in an organization, was proposed by Davis (1989), which indicates that Perceived Usefulness and Perceived Ease of Use are two determinants that affects individual whether intent to use the technology or not. Perceived Usefulness means an individual in an organization think if using specific program or system can improve his/her job performance. Perceived Ease of Use is defined as the degree of how easy an individual thinks learning to use a specific program or system. The rise of online shopping relied on the improvement of communication technology, and the perspective of technology acceptance is used much in previous research to explain the behavior of online shopping of consumers (Gefen & Straub 2000; Pavlou 2003; Koufaris 2002).

Venkatesh et al. (2003) empirically compare 8 user acceptance models, formulate the Unified Theory of Acceptance and Use of Technology (UTAUT), and validated it. After empirically comparison, several constructs were found to be direct determinants of intention or usage, and those were theorized into a model with four constructs: Performance Expectancy, Effort Expectancy, Social Influence, and Facilitating Conditions. There are also four moderators: Gender, Age, Experience and Voluntariness of Use. The variance explained by UTAUT is high, and it was interdisciplinary because it was validated among different human behavior models. UTAUT gave us ideas and basis of combing root constructs and determinants of behavioral intention. We were going to explore more factors in e-commerce context and look for what's new in cross-border online shopping.

### *Hypothesis development*

Based on previous research and UTAUT model, we tried to employ four dimensions from UTAUT together with other factors we found into a new model. We organized determinants that will influence purchase intention into: (1) consumer's perception of online shopping, (2) consumer's perception of online stores, (3) influence from people around the consumer, and (4) environmental factors that facilitate or limit consumer's behavior. We named these four dimensions as: (1) buyer factors, (2) seller factors, (3) social factors and (4) environmental factors.

These leads us to the following hypotheses:

H1a: Consumer's attitude toward price of product and its changes has significant influence on purchase intention.

H1b: The degree that consumer think about motivation and behavior of cross-border online platforms are trustworthy has significant influence on purchase intention.

H1c: The degree that consumer is willing to take a risk to use innovative cross-border online shopping service has significant influence on purchase intention.

H1d: Judgement of consumer's own ability to go cross-border online shopping has significant influence on purchase intention.

H2a: Consumer's attitude toward goods that is available via cross-border online shopping has significant influence on purchase intention.

H2b: Efficiency of cross-border online shopping has significant influence on purchase intention.

H2c: Consumer's perception of how good about the website overall operation, appearance or comparison to other websites has significant influence on purchase intention.

H2d: The degree whether consumer thinks the goods he/she bought via cross-border online shopping is a good deal and reasonable has significant influence on purchase intention.

H3a: The degree to which going cross-border online shopping can promote his/her image or status in one's social system has significant influence on purchase intention.

H3b: The degree consumer's perception of others think he/she should go cross-border online shopping has significant influence on purchase intention.

H3c: The influence of consumer's commitment and esteem to groups he/she belong to on purchase intention has significant influence on purchase intention.

H4a: The degree that cross-border online platform has protective structure to ensure consumer's data security in online transaction has significant influence on purchase intention.

H4b: Consumer's attitude toward third-party payment system on cross-border online platforms has significant influence on purchase intention.

H4c: The stereotypes come from the language of cross-border platform has significant influence on purchase intention.

H5a: Gender moderates the influence of determinants on purchase intention

H5b: Age moderates the influence of determinants on purchase intention.

H5c: Income moderates the influence of determinants on purchase intention.

H5d: Product type moderates the influence of determinants on purchase intention.

H5e: Hedonic or goal-focused shopping orientation moderates the influence of determinants on purchase intention.

## **RESEARCH METHODOLOGY**

### *Research model*

According to our classification of four dimensions of determinants, the goal of this study is to examine if the determinant has significant influence on purchase intention of cross-border online shopping. The research model and hypotheses are shown in Figure 1.

### *Research design*

This study was designed as a survey research. Data were collected from consumers who had ever committed cross-border online shopping. Each item of the questionnaire was measured by the Likert-7 point scale except the basic information of the respondents. All of the items were listed on Appendix 1.

For data analysis, we used partial least square (PLS) method, which is used to analyze the latent construct. This study used SmartPLS (Ringle, Wende & Will 2005), the tool which based on structural model, to run and validate the model.

Stages of analysis of this study are (1) descriptive statistics, (2) reliability (3) validity and (4) verification of hypothesis. Descriptive statistics analysis includes demographic information of the data and calculation of frequency of used cross-border platforms and bought product types. We use composite reliability (CR) and Cronbach's  $\alpha$  value to see if this model has enough reliability, and test factor loading of each item. Validity analysis includes content, convergence, and discrimination. The items listed in our survey were modified from previous study and reviewed to ensure content validity. Convergence and discriminant validity will be checked by average variance extracted (AVE) and factor loadings of each determinant. The last stage we use PLS algorithms to see the path coefficients and explanatory power of this model, and bootstrap method to test the significance of hypotheses.

## **DATA ANALYSIS AND RESULTS**

### *Demographic information, used platforms and purchased products by consumers*

Nearly 69% of the respondents were female, and 31% were male. The biggest age group is between 18 and 25. 22.7% have monthly

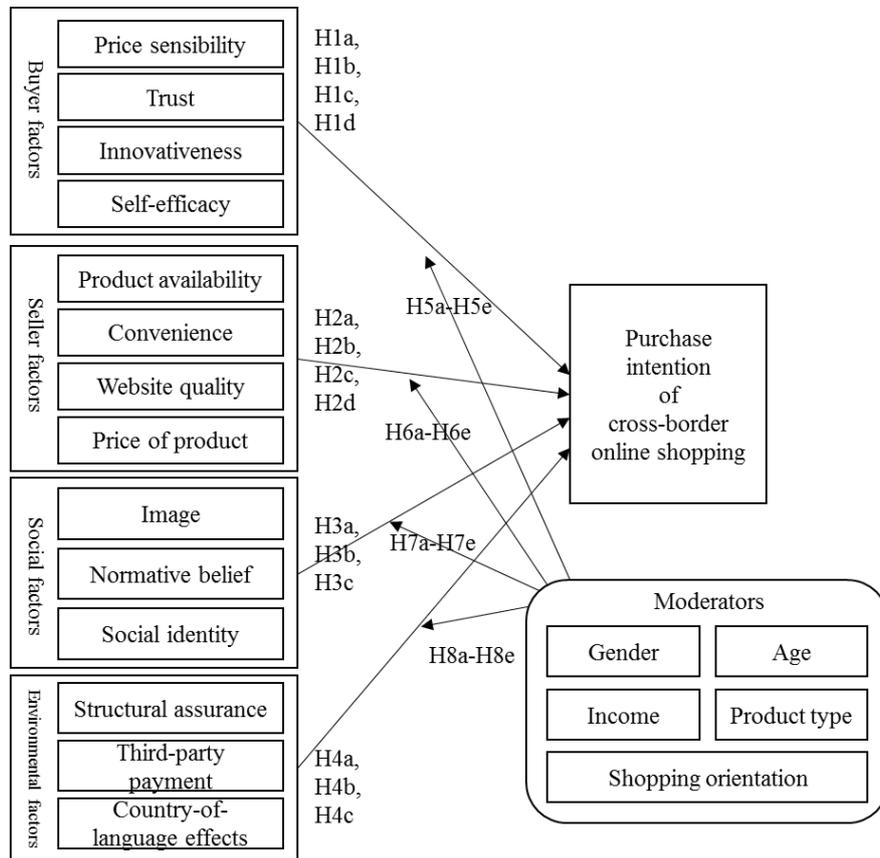


Figure 15. Research Model

income below NT\$5,000, and 19.8% earns between NT\$5,001 and NT\$10,000 per month. Most of the respondents (33.7%) make cross-border online purchase every half year. It is noteworthy that we had 14% respondents that had made only one cross-border online purchase ever.

We received names for at least 56 different cross-border e-commerce websites that consumers have used. If more than one consumer answered a particular brand official website, we counted as one name. The most popular platform is Taobao. Frequency of visit to popular websites are listed below. Besides, those who has been used only once are: Pinkoi, SSENSE, SIZE, Sephora, okwei, Tmart, USC, EAST DANE, luisaviaroma, travel agent, hotel reservation, HMV, Brandy Melville, Meikido, Toranoana, Surugaya, CDJapan, inspiring wave, Urban Outfitters, Farfetch, beautyexpert, VitaSprings, eVitamins, mercari, Alibaba, Mytheresa, Net-a-port, Juicy Couture, KoreaDepart, FashionWalker, Matchesfashion, OUTNET, and Selfridges.

We also calculated the quantity of products that consumers bought. Most purchased products are clothing, shoes, bags and books. Products and frequency are listed below. In analysis stage of this study, we referred to classification of product type by Nelson (1970), distinguished them into search goods and experience goods.

#### Verification of reliability and validity

Next we have to verify the reliability and validity of this model. Validity includes three considerations: (1) content, (2) convergence and (3) discrimination. We modified our questionnaire from previous developed items and discussed with experts to make sure we have enough content validity. Then we checked if AVE of each item is over 0.5 and factor loadings is over 0.5. After analysis, some of the determinants do not satisfy these thresholds. We deleted some items, and made this model comply with convergent validity. To examine discriminant validity of each determinant, we should compare square root of AVEs and correlations. If all the square root of AVE is bigger than any other correlation of this determinants and other one, this model has enough discriminant validity. The result listed below shows our model does have enough discriminant validity.

Suggested by Nunnally (1978), if every Cronbach's  $\alpha$  value of each item is between 0.5 and 0.6, then there's enough reliability. Every item, and that every Cronbach's  $\alpha$  value is over 0.6. Furthermore, all of the composite reliability of each item is over 0.7, suggested by Fornell & Larcker (1981). It means that this model reached internal consistency, and therefore it has good reliability.

#### Hypotheses testing

We used PLS algorithms and Bootstrap method to calculate path coefficient and significance of every item. We first tested the original model, then we added moderator one at a time to test the moderating effects. The explanatory power ( $R^2$ ) of original model is 54.2%. Results of hypotheses testing are listed below:

Table 1. Results of hypotheses testing

Path	Path coefficient	P	Testing result
Price sensibility → purchase intention	0.291899	0.000***	H1a supported
Trust → purchase intention	0.131066	0.014 **	H1b supported

Innovativeness → purchase intention	-0.029278	0.307	H1c not supported
Self-efficacy → purchase intention	0.096326	0.052	H1d not supported
Product availability → purchase intention	0.066581	0.107	H2a not supported
Convenience → purchase intention	0.234325	0.000***	H2b supported
Website quality → purchase intention	-0.057723	0.293	H2c not supported
Price of product → purchase intention	0.191385	0.000***	H2d supported
Image → purchase intention	-0.032213	0.441	H3a not supported
Normative belief → purchase intention	0.050719	0.246	H3b not supported
Social identity → purchase intention	0.035335	0.479	H3c not supported
Structural assurance → purchase intention	-0.045632	0.349	H4a not supported
Third-party payment → purchase intention	0.037078	0.401	H4b not supported
Country-of-language effect → purchase intention	-0.065593	0.094	H4c not supported

Under 99% confidence level, “price sensibility”, “convenience” and “price of product” has significant impact on purchase intention. Trust has significant influence on purchase intention under 95% confidence level.

## CONCLUSION AND DISCUSSION

### *Price sensibility and Trust*

Our study found that consumers who preferred low price had higher purchase intention, and this is empirically proved by the fact that consumers who go cross-border online shopping look for lower price of the product. Past research of e-commerce proved that trust toward online shopping is an important issue. In cross-border e-commerce, it is also important to build the bridge of trust between buyer and seller. Consumer’s trust toward cross-border online shopping significantly affects purchase intention. Innovativeness, another buyer factor we examined, has negative path coefficient toward purchase intention because the questionnaire is set in a such way that the higher the consumer scores, the more conservative this consumer will be. This finding met our expectation for innovativeness. Although self-efficacy didn’t have significance influence on purchase intention, its p-value is so close to the threshold. We think that the process of cross-border online shopping is usually more complex than domestic online shopping, so that also met our expectation.

### *Convenience and Price of Product*

We found that convenience and price of product have significant impact on purchase intention in cross-border online shopping. We inferred that if cross-border online shopping provides more shopping efficiency for consumers, then consumers will have higher cross-border online shopping intention. On the other hand, if consumers think transactions via cross-border online shopping are good deals, they will purchase more. Website quality and product availability, two other factors under seller factors, have no significant influence on purchase intention, but the path coefficients are positive. We inferred that consumers focus more on whether they can complete their purchase order when they use cross-border online platforms.

### *Social factors and Social Identity*

In this study, we organized three social factors: image, normative belief and social identity. All of these have no significant influence on purchase intention. We inferred that in recent context of cross-border online shopping, social influence doesn’t play an important role on affecting individual purchase intention. However, there’s still possibility that the form of social influence has changed, or the way that consumers will be affected by others is different from traditional domestic e-commerce. For instance, we didn’t include the concept of “word-of-mouth” in our study. In order to expand social influence in cross-border context, areas such as word-of-mouth can be taken into consideration to explore new ways of interpersonal interaction that affect consumer purchase intention. Incidentally, social identity, for some of the specific platform users, has significant influence on purchase intention. We inferred that social identity has more power in cross-border context than the other two factors.

### *Environmental factors and Country-of-language Effect*

This study hopes to provide a model which combined existing institution, technology and cultural factors. For that we put structural assurance, third-party payment and country-of-language effect into environmental factors for the study. Overall, environmental factors have no significant impact on purchase intention, however for some of the specific platform users, country-of-language effect has significant influence on purchase intention. We inferred that cultural and lingual factors still have influence in cross-border online shopping context.

### *Moderating effects*

According to our analysis, gender, income, age, experience goods and shopping orientation have significance moderating effects in the relationship between some specific determinants and purchase intention. For female, normative belief has significant influence on purchase intention. We inferred that female consumers perceive importanttake others’ opinion more seriously, and then be affected by it more easily. Income and age have moderating effects on the influence of third-party payment to purchase intention. It showed that consumers with different social and economic status have different opinion about using third-party payment while going cross-border online shopping. Impact of social identity on purchase intention is significant for those respondents who didn’t buy any experience goods. It meant that these consumers bought search goods via cross-border online, and their purchase intention is affected by the degree they devoted to social group they thought they were affiliated to. Moderating effects of hedonic/goal-focused shopping orientation are interesting findings of our study. Hedonic shopping orientation moderated the influence of third-party payment on purchase intention, and both orientations have significant moderating effects on the impact of trust on purchase intention. We thought that shopping orientation represents the shopping value that consumers look for, so the relationship among

shopping value, trust, and existing system can be taken into a deeper discussion in the future.

#### *Determinants and Platform types*

Our study found that if consumer use different types of platforms, the determinants that may cause significant influence will differ. Price sensibility was significant in all of the groups. Taobao-only users and C2C-only users had determinants in common: social identity and country-of-language effect. However, most of C2C-only users were also Taobao-only users, so it was expected the results are similar. Both B2C and C2C users scored similarly to the overall sample, except that trust for both B2C and C2C users had no significant influence on purchase intention. For B2C-only users, self-efficacy had significant impact on purchase intention, while convenience didn't. We inferred that B2C platforms include brand official websites and online retailers, which may have much difference from each other. This may be the reason that self-efficacy will impact purchase intention. Although we found that the significance of the determinants differs by the types of platforms, it is noteworthy that we used B2C/C2C for the basis of classification. The result may differ if basis is changed.

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# How Openness of Technology and Digital-Resource Readiness Benefit E-service Innovations

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## ABSTRACT

Over the past 20 years, information technology (IT) has become prevalent as a service delivery option. Today, digital platforms are commonplace in many industries and technologies, and can have a considerable potential impact on open technology investment, e-service quality, and customer satisfaction. They are central concerns for contemporary firms to obtain sustained competitive advantages in current fast changing markets and innovative customer demandingness. Due to the importance of service innovation in digital age, a conceptualization of e-service innovation is increasing required and emphasized. New e-services behooves businesses to execute e-service management and competitive e-service delivery with speed, surprise, and competitive disruption has attracted significant attention as an e-service innovation for competing effectively in the current digital environments. Further, implementing e-service innovation has become increasingly more challenging, driving managers to employ different technological resources (or capabilities) to enhance open technologies to carry out superior e-service innovations that can differentiate from competitors, in turn, attain superior firm performance. In order to facilitate e-service innovation, this study proposes that firms require to build open technologies and to promote e-service innovation practices. Correspondingly, the present study probes the relationships between “openness of technology”, “e-service innovation”, “digital-resource readiness”, and “firm performance”. Based on research model, this study assists business in building digital infrastructures, in order to manage new e-services and further then facilitate e-service innovation within openness-based digital service-oriented economic body.

## KEYWORDS

Openness; e-service innovation; digital-resource readiness

## INTRODUCTION

As many industrialized countries have transitioned to service-based economies and as Internet technologies have increased global trade, an increasingly growing stream of innovation studies has emerged that has attempted to identify factors that are crucial to e-service innovation. With regard to e-service innovation research, relevant issues, including co-creation (Chuang and Lin, 2015), interfirm codevelopment competency (Tsou and Chen, 2012), technology integration mechanism (Tsou, 2012a), knowledge integration mechanism (Tsou, 2012b), and dichotomic approaches (Di Guardo and Cabiddu, 2015), have been examined and thoroughly developed. Based on the previous research regarding antecedents of service innovation, however, maximizing service innovation requires openness to external ideas, commitment to design, an effective internal organization of resources, and the development of appropriate encoding linkages (Love et al., 2011). Indeed, innovation is a collective process based on an interplay between internal and external producers and carriers of knowledge (Anand et al., 2011). Hence, openness to external ideas is beneficial for innovation (Chesbrough, 2006; Zaltman et al., 1973).

As witnessed by recent developments, the role of open technology has been central to making e-innovations technically feasible and economically viable. Technology applications assess the value of these deployed IT resources, the capabilities between technology and the various aspects of an organization, and the conditions in which the innovative e-service products will be created or produced through information technology (IT) (e.g., ICT networks, such as Internet technologies, cloud computing, Apple and Android mobile operating systems or digital infrastructure). Accordingly, open technology is compatible with a great number of actors to enable just-in-time e-service provisioning through the integration of interactive interface and software components. This e-innovation can largely be termed “technology openness-enabled e-service innovation,” which involves new combinations of open technology, collaborative partnerships, and physical components to create novel e-service offerings. Therefore, the openness of technology appears to be an important foundation in the e-service innovation process and converts internal connectivity (i.e., knowledge

interfaces), digital innovation strategy (i.e., decision making), and collaboration (e.g., customer interactions, interorganizational relationships, co-production) into new e-services.

In the 21st century, electronic application mainly assesses the extent of deployed digital resources between technology and various aspects of an organization and the situation in which collaborative services will be created or produced. The vital question for firms in dynamic and diversified electronic environments is: should extending the scope of digital resources be viewed as generating value that leads to superior e-service innovation? Thus, it would be a top priority for firms to be able to evaluate their readiness for adopting digital resources prior to considering other issues pertaining to the enhancement of e-service innovation. In particular, based on Karimi et al.'s (2009) work, we propose two constructs that define a firm's readiness for digital resources: the reach and the richness of a firm's knowledge and processes. Therefore, a moderating view suggests that the openness of technology is inherently valuable to the extent that digital-resource readiness facilitates its effect on e-service innovation.

## LITERATURE REVIEW AND HYPOTHESES DEVELOPMENT

### *Openness of technology*

The openness of technology concerns the adoption of open system technology to enhance the compatibility of internal (or external) applications as well as to promote data communication and cooperative computation among private processes. Open system technology is defined as an approach to operate a set of standardized interfaces across all platforms and vendors that empowers the flexibility of the IT infrastructure and allows network users to work together (McGarry, 1993). Open system technology is characterized by "interoperability" that provides a sufficient interoperability environment that enables two distributed processes to share selective data with one another and enhances coordination among their process operations, implying that a cooperative computation is occurring (Chau and Tam, 1997; Nutt, 1990). In addition, there are two major mechanisms for interoperability: interface bridging (i.e., map client and server interfaces to a common representation) and interface standardization (i.e., two-way map between client and server) (Wegner, 1996). At the same time, "interconnectivity" is another characteristic that favors the existence of open system technology by bridging the gaps between the islands of private information to contribute information sharing and applications across different companies (Chau and Tam, 1997; McClain, 1991) and by creating integrated and distributed information systems (Nicol et al., 1993). Thus, based on the concept of open system technology, we propose that the openness of technology reveals the existence of two different openness dimensions, namely technology interoperability and technology interconnectivity.

### *e-Service innovation*

E-service innovation is defined as a service delivery innovation that is created by a service provider using technical capabilities involving interaction with partners to improve their service delivery and to tailor their services to meet customer demands through electronic technologies (Tsou and Chen, 2012; Chuang and Lin, 2015). In the service innovation literature, an ongoing debate concerns the extent to which radical and incremental innovations are meaningfully separable aspects of innovativeness (Avlonitis et al., 2001; De Brentani, 2001; Menor et al., 2002). Because this study is concerned with the greatest and least degrees of e-service innovation, we differentiated e-service innovation into incremental and radical e-service innovations. Based on Berry et al. (2006) and Nijssen et al. (2005), radical e-service innovation is defined as fundamental changes in new services that represent revolutionary changes in service benefits through internet technologies. In contrast, based on Connor (1999) and Slater and Narver (1999), incremental e-service innovation is related to customer-led strategies that focus on manifest needs through internet technologies.

### *Openness of technology for e-service innovations*

Open technology is critical for innovative designs (Zafarana, 2001) and enables the interconnectedness and interoperability of data that are gradually stored in a knowledge base for subsequent innovation development (Chau and Tam, 1997). This knowledge may consequently support technical personnel with sufficient IT skills in adopting and implementing new e-services. In facilitating digital service innovations, technological options play a key role in linking new service concepts, client interfaces, and new service delivery systems (den Hertog, 2000). It is particularly important to coordinate individual technology

transactions with each other. This requirement implies that firms have to co-design and co-operate an open IT infrastructure (i.e., open technology) with partners and manage the accompanying technological collaboration. For example, den Hertog et al. (2010) indicated that the combination of the iPhone with the iStore shows that important new e-services can be developed in large communities linked through open technology platforms and networks of businesses. Without such open technology platforms and networks, these digital service innovations would not become as successful or even exist.

Notwithstanding the significance of technology and despite a growing number of studies on IT for service innovation (e.g., Chen and Tsou, 2007; Chen et al., 2009; Rai and Sambamurthy, 2006; Tsou, 2012a), IT experience bundled with other resources enhances the firm's learning of service innovation information and the coordination of service innovation activities (Yen et al., 2012). Indeed, e-service innovation combined with an openness approach to business within an open technology platform is an effective and powerful way to grow and compete in the 21st century. As we discussed in the previous section, e-innovation may depend highly on technology infrastructures for the interoperability and interconnectivity concerns. When a firm is considering technological lockout effects after implementing a new e-service innovation, a closed technology infrastructure could be a critical negative factor when making the decision. In the IS field, most open technologies are developed and directed by official or industrial institutions. Firms that adopt open technologies that enable e-service innovation can reduce the risk of technological lockout, thereby increasing their willingness to utilize them. In most cases, e-service innovation requires firms to open networking connections to integrate or interchange information resources. Therefore, this study considered technology interoperability and interconnectivity affecting radical and incremental e-service innovations. We argue that the openness of technology is the most effective way to organize and act for e-service innovations. Accordingly, we hypothesize the following:

H1: Technology interoperability has positive effects on a) radical and b) incremental e-service innovations.

H2: Technology interconnectivity has positive effects on a) radical and b) incremental e-service innovations.

#### *The moderating roles of knowledge and process reach and richness*

In spite of the focus on the openness of technology, digital-resource readiness is also an important factor in the adoption of e-service innovations. Knowledge reach refers to the comprehensiveness and accessibility of codified knowledge that is available to a firm. Knowledge richness refers to the quality of information. Digital process reach involves the implementation of digitized processes that tie activity and information flows together across departmental units, functional units, and geographical regions as well as between value network partners (including suppliers, customers, and vendors). Digital process richness is associated with the quality of the information collected about transactions in these processes. Process richness improves the quality of information available to participants by making information timelier, more accurate, relevant, and customized (Overby et al., 2006).

The use of digital resources is facilitated when existing resources and capabilities allow preferential access to future opportunities for growth. Enhancements in the breadth of resources (reach) and the quality of information (richness) available to the firm improve its ability to sense and respond to environmental changes, thereby making it more agile and better able to gain competitive advantages (Overby et al., 2006). If a business' ability to possess technology interoperability and interconnectivity in service creation and service delivery processes depends on the extent to which knowledge and process reach as well as the extent to which richness directs a firm to improve its preparedness and flexibility concerning invaluable resources, then an interaction between knowledge, process reach and richness and the openness of technology can be expected. Therefore, it is reasonable to suggest that the impact of technology interoperability and interconnectivity on e-service innovation performance is positively moderated by a firm's digital-resource readiness, that is, the reach and richness of its knowledge and processes. Meanwhile, this study suggests that firms that possess high reach and richness in their knowledge and processes will have greater e-service innovation performance; in other words, the reach and richness of knowledge and processes will moderate the relationship between the openness of technology and e-service innovation performance. Thus, we develop the hypotheses below:

H3: Knowledge reach and richness moderate the relationship between technology interoperability and a) radical e-service innovation as well as b) incremental e-service innovation.

H4: Process reach and richness moderate the relationship between technology interconnectivity and a) radical e-service innovation as well as b) incremental e-service innovation.

## CONCLUSIONS

### *Contributions to research*

This proposal makes two primary theoretical contributions. First, this study contributes to the theoretical development of a conceptual model for explaining the relationships between the openness of technology, e-service innovations, and digital-resource readiness. Despite the increasing importance of digital technology platforms, cloud computing, organizational knowledge, and new service delivery, few studies have discussed these relationships, and this deficiency is serious because of the increasing importance of new digital services (i.e., e-service innovations). In particular, we highlight two e-service innovation dimensions: radical and incremental e-service innovations. We propose that radical and incremental e-service innovations are important because they depict how firms continually develop technological resources and digital resources to shape their e-service innovations. It will be important for researchers to pay attention to the radical and incremental e-service innovations in our model. Second, researchers from different disciplines should work together to identify and develop a common and general determinant that reflects the effort to deliver customer values for an organization and its customers. Most importantly, the openness of technology, digital-resource readiness, and e-service innovation practices must combine value creation for all in a balanced way to be successful in the long run (i.e., sustained competitive advantages). In this respect, the technology interoperability and technology interconnectivity that appear in our proposed radical and incremental e-service innovations might provide valuable insights for exploring the next step in e-service innovation or IS research in the years to come.

### *Contributions to practices*

This proposal has four practical managerial implications. First, the openness of technology is valid for the enterprise and business unit. Understanding the key technology interoperability and technology interconnectivity that may affect radical and incremental e-service innovations will put practitioners in a better position to develop appropriate open technology strategies (and/or platforms) for customer service resource deployment and, consequently, to enhance a firm's e-service innovations. Second, it is imperative for top management to carefully consider the role of senior managers (e.g., IT and marketing managers) in e-service innovation initiatives. Before beginning major e-service innovation programs, managers may need to consider investing in the IT-related resources and capabilities that will be used to build open technologies. Similarly, managers are often faced with supporting digital innovation programs and having such a collaborative IT mechanism in place may guide them in adopting guidelines and managerial postures that will ensure successful openness of technology. We suggest that if firms consider open technologies, they may be able to sense changes, organize capital, knowledge, and relations as well as meet changing customer needs in a timely manner and convert market change challenges into new e-service opportunities. Third, in the e-service innovation process, paying attention to digital-resource readiness is very important. Top managers should prepare necessary digital resources for developing new digital services that can facilitate e-service innovation practices. After identifying the customer need (e.g., radical or incremental) and analyzing the types of customer need, different types of customer needs can be managed accordingly. The company can use open technologies to provide the digitalized knowledge systems or e-service processes that the valuable customer needs. Doing so can make e-service innovation more competitive and can better meet the needs of customers. Only by possessing digital resources with e-service innovation practices can the company establish a long-term steady relationship and gain success in e-service innovation, thereby attaining radical and incremental e-service innovations. Fourth, managers are advised to carefully consider new service delivery, digital innovations, digital resources, new open technologies, and judgment, even within the context of existing practices, products, and business units. Uncertainty and novelty are hardly the domain of a few industries or business practices; they are indeed ubiquitous in an advanced industrial economy. Managers must consider the core questions of strategic positioning,

knowledge platform, organizational service design processes, and technology infrastructures, which are central to processes of creating and capturing economic value.

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# Innovation Resistance Factors and Behavioral Research of Inner Members of Media Companies on the Introduction of ICT-Based Media Technology Innovation: Focused on the MTA Framework

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Nowadays, as the media environment changes rapidly due to the development of ICT technology, content supply and consumers' usage patterns are rapidly shifting to IP-based media.

In order to respond to this phenomenon, traditional media companies including terrestrial broadcasters are making efforts to introduce new ICT-based new media technology innovation into the organization in order to adapt to new media environment and secure competitiveness.

In this study, based on the understanding of the media environment brought about by ICT technology, the terrestrial broadcasters, who are the representative players of traditional media companies. In addition, we try to find out the correlation between the innovation resistance factors of inner members and the diffusion of innovation in the organization, and explore strategies for innovation resistance management and diffusion in the organization.

In addition, we analyze the media companies that lack research on innovation resistance and innovation diffusion from research on innovation resistance and innovation diffusion, which have been studied as acceptance of high technology products or services, and especially terrestrial broadcasters. This study investigates the factors affecting innovation resistance and innovation diffusion of inner members of terrestrial broadcasters who are trying to introduce new innovation technologies related to the media industry.

The PLS path analysis of this study for terrestrial broadcasters is summarized as follows. First, the conversion cost and technical uncertainty were found to be statistically significant causal relations to innovation resistance. Second, the results show that innovation resistance influences the diffusion of new media technology innovation in the organization. Third, the characteristics of the professional group positively influenced the diffusion of innovation.

In the future research, it is expected that the researchers will be able to derive more meaningful implications and research results by focusing on the research subjects as the starting point of the media industry value chain.

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Key Words: Media Industry, Innovation Resistance, Innovation Diffusion

## I. INTRODUCTION

### *1. Research Background and Purpose*

With the development of ICT technology, new media are threatening existing media companies that have grown under the protection of regulatory authorities. Consumers can enjoy the contents they want without being bound to time and place, and easily share and reproduce their experiences with other users (Lee, Lim & Ahn, 2011). As a result, the frequency of using existing media is decreasing (Oh & Yum, 2015). As an Internet-based media environment has been emphasized in media industry, existing media including terrestrial broadcasters are required to produce and distribute contents in new ways (Kwak, Park; & Lee, 2013).

However, the introduction of new technologies and changes in processes will inevitably cause organizational members of existing broadcasters to maintain their current status against the requirement of changing their behaviors (Zaltman & Wallendorf, 1983). In the meantime, most of the researches focused on how the consumers respond to the introduction of new technologies in manufacturing and IT services. Because the media industry is a regulated and government-protected industry, other research strategies are needed. This research examines the factors affecting the innovation resistance and diffusion of inner members when media companies accept and acquire new technologies.

The purpose of this study is to empirically investigate the factors influencing innovation resistance by defining the factors and analyzing the result of research. Moreover, this study aims to suggest new strategy to minimize

innovation resistance by deriving conclusion concerning necessities of managing factors of innovation resistance.

## **2. Scope of Study**

For the purpose of this study, in the beginning, media industry and innovation technology are defined by referring to the research papers and reports. This study discusses the innovation resistance model, which is the theoretical base of innovation resistance and diffusion within an organization, and the framework that explains the theory and the resistance factors. Research model and hypothesis are presented with observational variables and potential variables. After that, operational definition of variables and the method of data collection and survey are explained. The hypothesis are verified through structural equation model focused on a motivation-threat-ability framework. With these measures, research results and implication are derived while suggesting the limitation and future direction of the study.

## **II. THEORETICAL BACKGROUND**

### **1. Media Industry**

Contents are significant in the media industry. Because content creators' knowledge and creativity are essential to the value of contents, media companies are more likely to focus their organizational capabilities on employing the creative. Changes in the media industry are closely related to the development of ICT technologies. The development of technology has always influenced on generating or formatting new area of the media industry.

With the recent advancement of ICT technologies, such as the Internet and Smart phone, the center of consumption has shifted to the Internet-based channels, and various companies, such as Smart media, OTT service, cable MSO and so on, enter the media market and threaten existing TV broadcasters.

However, terrestrial TV broadcasters are ineffective to change because they have to pursue public interests based on fairness and there are many regulations.

### **2. Technology Innovation**

It is necessary to clarify the concept of media technology innovation involving an introduction of the latest technology such as ICT. Generally, innovation is the implementation of dramatically improved products, processes or organizational methods. According to 'Oslo Manual', OECD corporate innovation standard manual, there are four types of classifying innovation: product innovation, process innovation, marketing innovation, organizational innovation. In this study, technology innovation applied to media companies is defined through literary research and empirical research.

Technology innovation refers to innovation activities in technology field which indicates theoretical and practical knowledge, talents, and substance that can be used to develop products and services (Burgelman & Kosnik, 1988). In addition. It can be defined as a series of phenomena in which a new product or service is produced, marketed and traded through a new combination of process, market, material and organization (Shumpeter, 1934).

Recently, as Information Technology has rapidly developed and the efforts for technology innovation have been strengthened, a large number of people participate in research and development activities jointly, and the concept of open innovation has emerged in response to this tendency.

Open innovation refers to a new way of innovating a company by bringing external technology into the company, or by transferring technology from the company to the market in order to improve performance of the innovation and ultimately increase the value of the enterprise (Chesbrough, 2003).

Innovative companies face many obstacles. Strategic action is needed to overcome or remove causes of hindrance to innovation activities (March et.al., 2002). Because innovation drives change, innovative organizations must improve their performance by adjusting internal and external functions as responding to external needs. Organizations trying to retain innovative superiority recognize new opportunities for efficiency and effectiveness. Because the environment is changing, organizations must adopt innovation over time, and innovation leads them to achieve a competitive advantage and thus contributes to organizational performance (Damanpour, 1991).

In order for media companies to survive in a rapidly changing media ecosystem, it is essential for them to acquire media technology innovation represented by ICT and to internalize it.

### ***3. Innovation Resistance Theory (IRT)***

Ram (1987) defines innovation resistance as a type of resistance to change caused by consumers when they have to adopt innovation. Innovation resistance itself is not a negative attitude, but a resistance to change caused by innovation. The resistance of consumer is not the opposite concept of innovation adoption. It is a natural psychological state and the inevitable experience of adopting innovation (Ram, 1987).

Resistance to change at the organizational level implies the reaction of the members to adhere to the current situation with regard to the changes that the organization pursues (Piderit, 2000). Many previous studies on organizational change have shown that members resist change. In other words, in the situation of change and innovation, the resistance and adoption of the members means both acceptance and rejection behavior, not separate and opposite concepts.

It is a general view that innovation resistance is an obstacle to innovation, but it is not necessarily negative. Resistance is a natural phenomenon in human beings and organizations. Therefore, innovation resistance should not be regarded as unconditionally negative, but as a key issue to manage and solve.

### ***4. Innovation Diffusion Theory (IDT)***

Innovation diffusion is the process by which new ideas, practices, products or services are communicated through a certain channel among society members over time. Adopting innovation is the process of using innovation.

Davis (1989) proposed a technology acceptance model (TAM) and Venkatesch & David (2000) proposed extended technology acceptance model (TMA2). Both models provide an in-depth understanding of the process of innovation adoption by presenting causal relationships between factors influencing information technology acceptance. In other words, the technology acceptance model reveals what factors affect the process of accepting the information technology introduced by the organization to improve its performance (Davis et al, 1989). Simplicity is both a strength of the model and a disadvantage. The results of the various empirical researches show that the diffusion of innovation is faster unless members feel that innovation is difficult to understand and use, which means the perceived complexity of innovation is low.

Innovation Diffusion Theory suggested by Rogers (1962) has been widely used as a theoretical framework for the study of individual innovation adoption and innovation diffusion at the social level. The theory presented the innovation tendency which is psychological characteristic of consumer as another factor that can explain the adoption of the innovation. The innovation tendency, defined as the degree of adoption new ideas, is estimated by the relative time taken to adopt the innovation. The theory categorizes social members based on innovation tendency and classifies them into five groups -innovators, early adopters, early majority, late majority, laggards (Rogers, 2005).

### ***5. Motivation-Threat-Ability (MTA) Framework***

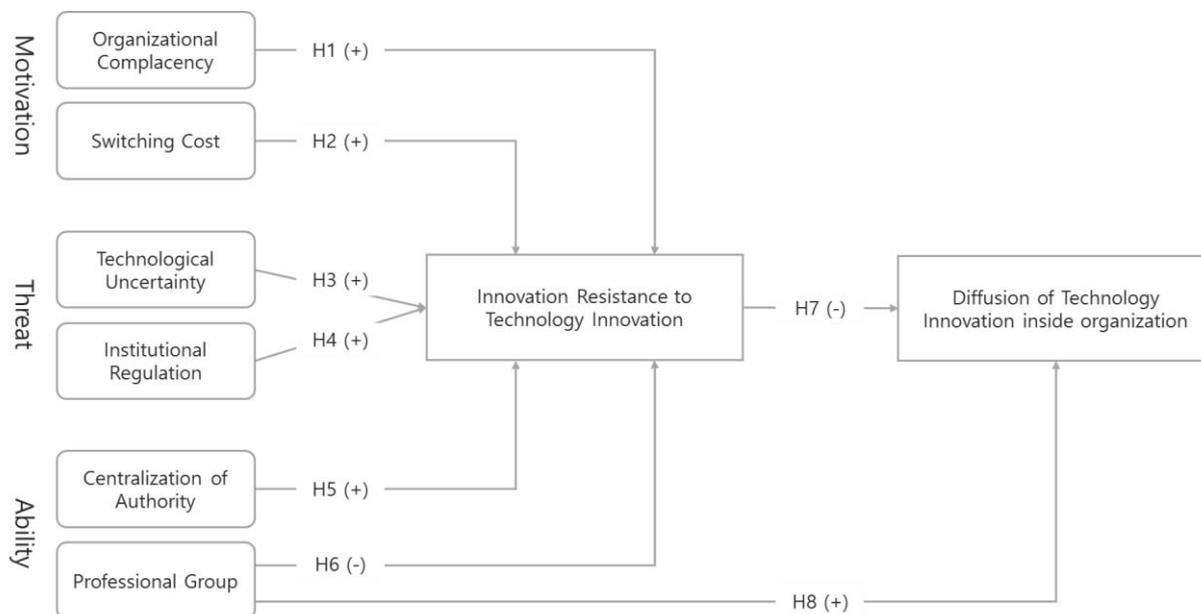
A motivation-threat-ability framework has been developed on the basis of the motivation-opportunity-ability (MOA) paradigm (Batra and Ray, 1986). MOA paradigm has two assumptions; one assumption is that technology innovation is brand-new knowledge or information which are essential to use production or consumption; another is that organizational decisions on innovation acceptance are information processing outcomes. Bao (2009) exploits MOA paradigm to illustrate the innovation resistance to technology innovation in the organization. He explains that when consumers accept technology innovation products, they sometimes systematically reject the products that are superior to prior ones. He suggests a motivation-threat-ability framework which replaces opportunity factor of MOA with threat. MTA framework considers organization complacency and switching costs as motivation factor, and technological uncertainty and political threat as threat factor, and formalization structure and centralization structure as ability factor.

## **III. RESEARCH MODEL AND HYPOTHESIS**

### ***1. Research Model***

Existing research on technological innovation is concentrated on products or processes followed by the introduction of new technologies, and there are few studies on media companies regarding technological innovation. In addition, ICT based media technology innovation is not only about introducing new technologies to media companies, abut also affecting organizational structure and organizational change. In

this research, therefore, the research model was designed based on the theoretical researches about media industry, technological innovation, resistance to innovation, diffusion of innovation and the reaction of the users to the introduction of new technology. Through the research model, this study tries to identify correlation between the resistance to change of inner members and factors of impeding use of innovative technologies, and to find out the relationship between observational variables with innovation resistance. In the model, there are six observational variables, such as organizational complacency, switching cost, technological uncertainty, institutional regulation, centralization of authority, professional group to identify mediating effect.



<Figure 1> Research Model

## 2. Research Hypothesis

### 2.1 Motivation Factors of Introducing Technological Innovation

In order to achieve continuous innovation, overcoming cynicism has to be done primarily by management and innovators. Organizational cynicism is an attitude that members perceive their organizations in negative view (Dean, & Dharwadkar, 1998) and it also indicates distrust and disappointment of the organization. Based on the previous researches, the organizational complacency was defined as cynicism and rejection about change. Switching cost is the opportunity cost that arises from inconsistency between current consumption and past investment (Klemperer, 1987). Among them, exploration and learning costs are the material and immaterial costs for exploring and learning necessary information and service characteristics to utilize new service. In this research, switching cost is defined as the time and effort to understand new technologies and apply them to business processes. The hypotheses about the effect of organizational complacency and switching cost on innovation resistance are as follows.

H1: Organizational complacency which rejects change and maintain current status will positively affect innovation resistance of organizational members to accept new technology.

H2: Switching cost which is time required for being aware of change of business process due to the introduction of new technology will positively affect innovation resistance of the members in accepting new technology.

### 2.2 Threat Factors of Introducing Technological Innovation on Media Companies

Technological uncertainty arises from the uncertainty of emerging competitive technologies or providing new solutions in combination with other technologies (Jeff Dyer & Nathan Furr & Curtis Lefrandt, 2014). As the proportion of new inventions increases throughout the overall industry, technical uncertainty also increases. With the emergence of IP based media contents, traditional regulations cause inconsistent restrictions on media. In particular, smart media has a development model led by market and technology. In the market, various services and business models are executed between the users and media companies, and the ripple effect appears later. Thus, regulations related to media are not only obstacles to service activation, but also can constrict autonomy

and creativity of media companies. Based on the previous studies, this study sets up the hypotheses about the effect of uncertain prediction to direction of technological innovation and absence of standardization and about the effect of various external regulations surrounding media companies on innovation resistance of organizational members.

H3: Technological uncertainty will positively affect innovation resistance of organizational members to accept new technology.

H4: Institutional regulations such as broadcasting law will positively affect innovation resistance of organizational members to accept new technology.

### ***2.3 Ability Factors of Media Companies about Technological Innovation***

Ram & Jung (1991) designate the adoption of innovation in organizational units as “forced adoption”, where the greater the centralization of authority, the greater the resistance although organizational members use the technology. Interactive organization whose members are highly engaged in decision-making is positive for technological innovation (Anderson and West, 1988). An expert is the one who performs a job in a professional field, and Martin & Shell (1988) defines a person as having a specialized or technical education who can use their knowledge to perform their work. It is well-known that professional group in media companies has generally shown positive and open mind on introduction of new technology for improving quality of media contents. Based on the previous studies, this study establishes the hypotheses about the innovation resistance influenced by members’ reaction toward unilateral notification of introducing new technology and about the effect of professional group in an organization on innovation resistance.

H5: Centralization of authority will positively affect innovation resistance of organizational members to accept new technology.

H6: The organization consisting of professional group will negatively affect innovation resistance of organizational members to accept new technology.

### ***2.4 Individual Attitude and Behavior on Innovation***

Rogers (1995) defined adoption in terms of innovation and change as a process of psychological progress from beginning to final acceptance. The process of adopting innovation is the process of strengthening decisions about executing or maintaining innovation, and it is the process of deciding whether to understand innovation, form an attitude to innovation, or adopt innovation. Based on the preceding research, this study shows that the larger the resistance of innovation to the introduction of new technology is, the more negative it is to diffuse new technology. Many media companies with professional groups are actively adopting and diffusing new technologies to improve quality of media contents.

H7: Innovation resistance of organizational members to accept new technology will negatively affect diffusion of technological innovation.

H8: Media companies composed of professional groups will positively affect the diffusion of technological innovation.

## **IV. METHODOLOGY**

### ***1. Research Design***

#### ***1.1 Research Subject***

Because of the realistic restriction, it was impossible to conduct research on all media companies, so research subjects are limited to three major terrestrial broadcasters among the domestic media companies. The reason of choosing the broadcasters is that terrestrial broadcasting is typically regulated by broadcasting law and is difficult to invest to cope with the new environment and technologies. Moreover, the broadcasters are losing their dominant status in the media market with the advancement of ICT technology, and the pace of technological innovation is relatively rapid.

#### ***1.2 Data Collection and Sampling***

In this research, self-administered questionnaire survey has been conducted from November 21<sup>st</sup>, 2016 to December 21<sup>st</sup>, 2016 through Google Docs without pilot survey due to time limitation. The subjects of the survey are the employees of three major domain terrestrial broadcasting companies, such as KBS, MBC and SBS. The type of sampling is convenience sampling considering constraints of time and cost. Due to the

characteristics of the researcher’s job, total 216 people who have various background responded to the survey and 36 untruthful answers were extracted. Thus, total 180 answers of the survey were used in the final analysis.

**2. Operational Definition of Variables**

In this research, based on the preceding researches, observational and potential variables are defined. Organizational complacency is defined as cynicism about change or rejection of change due to the conservative organization (Cummings & Worley, 1993). The fundamental cause of resistance due to the use of new information system is considered as cost and threat followed by the change (Kim & Kankanhalli, 2009). Bao (2009) insists that switching cost is economic constraints which reduce the perceived benefits of organizational members in accepting technological innovation. Technological uncertainty arises with an emergence of new technology and solution (Jeff Dyer & Nathan Furr & Curtis Lefrandt, 2014). Broadcasting law has not reflected the new trend of media industry in spite of strong needs on change with the appearance of new cross-border media (Lee, 2007). The more centralization of authority are greater, the more innovation resistance is greater (Ram & Jung, 1991). The structure of organization which members participate actively decision making process and interact with others has positive effect on technological innovation (Aderson & West, 1988). Innovation Resistance is the sense of being threatened by change and the attitude to maintain existing process (Zaltman & Wallendorff, 1983). The diffusion of innovation are generally defined as the frequency of perceiving new technology and its use. All of the variables are measured using Likert scale 7 point.

*<Table 1> Operational Definition*

<b>Variables</b>	<b>Operational Definition</b>	<b>Reference</b>
<b>Organizational Complacency</b>	The degree of cynicism about change or rejection of change due to the conservative organization	Cummings & Worley (1993)
<b>Switching Cost</b>	The degree of time and effort cost which make members perceive the benefits less	Kim & Kankanhalli (2009), Bao (2009)
<b>Technological Uncertainty</b>	The degree of attitude toward the use of new technological innovation	Jeff Dyer & Nathan Furr & Curtis Lefrandt (2014), Bao (2009),
<b>Institutional Regulation</b>	The degree to which current broadcasting law restrict the use of new media technology	Lee (2007)
<b>Centralization of Authority</b>	The degree of centralizing authorization and control to minority of organization	Ram & Jung (1991),
<b>Professional Group</b>	The degree of ability to utilize new media technology without any aids and difficulties.	Anderson & West (1988), Ruekert et al. (1985), Bao (2009), Martin & Shell (1988),
<b>Innovation Resistance</b>	The degree of rejection to introduce new media technology and process of organization	Zaltman & Wallendorf (1983), Ellen, Bearden & Shama (1991)
<b>Innovation Diffusion</b>	The frequency of communicating with colleagues and adopting new media technology to change work process	Ram & Jung (1991)

**IV. DATA ANALYSIS AND RESULTLS**

To statistically prove the hypothesis of this research and research model, a PLS path modeling was utilized through Smart PLS 2.0 using bootstrap method. It is an appropriate model to analyze small size of sampling and the correlation between factors of innovation resistance and actual behaviors. In order to verify the validity of the measurement tools, the correlation and validity of the variables were verified by exploratory factor analysis. The reliability of the variables was analyzed using the Cronbach alpha test.

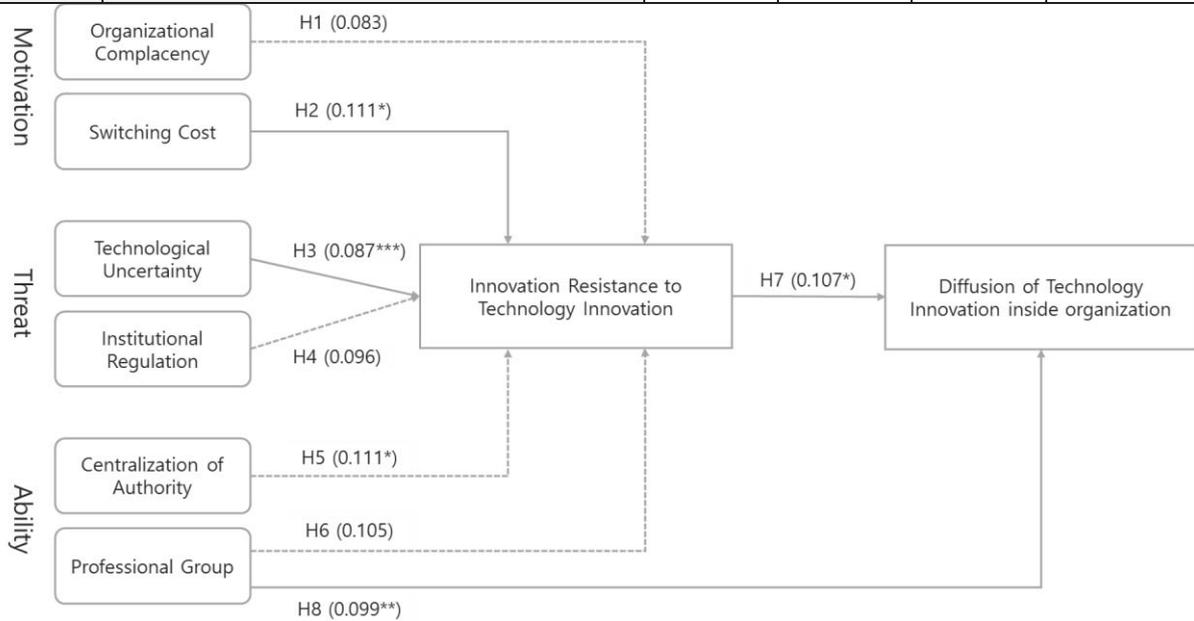
Through exploratory factor analysis, correlation and validity of variables are verified since eigenvalues of most factors are above 0.4 excluding organizational complacency. Every variables except organizational complacency has internal consistency reliability because the values of Chrobach alpha in most factors are above 0.7 which is a reference value. Model’s goodness of fit, in this research, was verified to hypotheses test and interpretation of result.

Path analysis indicates setting of casual model between variables and the efficiency of influence on connected path between variables. Through the research model and hypotheses test results, it is shown that 4 hypotheses out of total 8 hypotheses were statistically significant. Adoption and dismissal of hypotheses are statistically proved based on t-statistic, and hypotheses are generally adopted when t-statistic is above 3.291( $p < 0.001$ ), 2.807( $p < 0.01$ ), and 1.96( $p < 0.05$ ). It is proved that H1 hypothesis, Organizational complacency which rejects change and maintain current status will positively affect innovation resistance of organizational members to accept new technology, is rejected as t-statistic is less than the statistical significance level. H2 hypothesis, Switching cost which is time required for being aware of change of business process due to the introduction of new technology will positively affect innovation resistance of the members in accepting new technology, is statistically proved under 5% of statistical significance level ( $t = 2.02 > \pm 1.960$ ). H3 hypothesis, Technological uncertainty will positively affect innovation resistance of organizational members to accept new technology, is adopted under 0.1% of statistical significance level ( $t = 4.83 > \pm 3.291$ ). H4 hypothesis, Institutional regulations such as broadcasting law will positively affect innovation resistance of organizational members to accept new technology, is rejected as the effect is statistically insignificant. H5 hypothesis, centralization of authority will positively affect innovation resistance of organizational members to accept new technology, is rejected as t-statistics is less than the statistical significance level. H6 hypothesis, the organization consisting of professional group will negatively affect innovation resistance of organizational members to accept new technology, is rejected as t-statistics is less than the statistical significance level. H7 hypothesis, Innovation resistance of organizational members to accept new technology will negatively affect diffusion of technological innovation, is adopted under 0.1% of statistical significance level ( $t = 3.33 > \pm 2.807$ ). H8, Media companies composed of professional groups will positively affect the diffusion of technological innovation, is adopted under 1% of statistical significance level ( $t = 2.96 > \pm 3.291$ ). The research model after hypothesis verification is shown in <Figure 2> below.

<Table 2> Result of PLS Structural Modeling (T Statistics)

Hypot he sis	Path	Original Sample (O)	Sample Mean (M)	Standard Error (STERR)	T Statistics (O/STERR)
H3	Technological Uncertainty → Innovation Resistance	0.421628	0.443068	0.087245	4.832703***
H6	Professional Group → Innovation Resistance	-0.004007	-0.008739	0.105129	0.038112
H8	Professional Group → Innovation Resistance	0.296302	0.293326	0.099775	2.969708**
H2	Switching Cost → Innovation Resistance	0.226524	0.223801	0.111837	2.025486*
H4	Institutional Regulation → Innovation Resistance	0.093598	0.085973	0.096229	0.972662
H1	Organizational Complacency → Innovation Resistance	0.08742	0.09153	0.083773	1.011569

H5	Centralization of Authority → Innovation Resistance	-0.066922	-0.049237	0.11128	0.601382
H7	Innovation Resistance → Innovation Diffusion	-0.348177	-0.34918	0.107724	3.232123***



\*\*\* : 0.1% significance level, \*\* : 1% significance level, \* : 5% significance level

<Figure 2> Research Model Test Results

## V. CONCLUSION

In this study, the hypotheses are empirically analyzed and presented to the media companies, especially the terrestrial broadcasters, who have not studied research on innovation resistance and innovation diffusion beyond the research that has been studied focused on adoption of high technology products and services. This study examines the factors affecting innovation resistance and innovation diffusion of inner members of terrestrial broadcasters who intend to introduce new innovation technologies surrounding the media industry due to ICT development. To analyze the correlation between variables, a research model was designed and a PLS path analysis was conducted using structural equation modeling.

The result of hypotheses test, through path analysis, shows switching cost and technological uncertainty positively affect innovation resistance and there is a significant casual relation. This indicates that media industry has a high initial investment cost and has barriers to enter that affect innovation resistance of inner members. Moreover, innovation resistance has impact on innovation diffusion of new media technology inside organization. It means innovation resistance negatively affect innovation diffusion. In addition, professional group has positive influence on innovative diffusion. The characteristic of the tasks, such as learning cases of diverse field, analyzing trends to deliver fascinating contents, relates to their open attitude toward new media technology and its diffusion.

Furthermore, this study has significant meanings academically and practically. In an academic view, exploratory research about factors of influencing innovation resistance was conducted to media companies, and as a result, the factors of innovation resistance of media companies was defined. Through the literature review, Bao's (2009) MTA framework, which explains innovation resistance in adopting technological innovation, has been modified for media companies and innovation resistance has been defined contrary to the previous researches on general innovation resistance model about adopter of innovation.

In a practical view, as terrestrial broadcasting has to compete with IP-based media due to the development of ICT technology, the media ecosystem is developing in a direction that inner members have never experienced before. At this point, switching cost and technological uncertainty, main influencing factors of innovation

resistance, have shown the rejection of new media technology and indicated that inner members are afraid of learning new technology and adopting new change. Moreover, inner members are also responding to institutional regulation.

However, this study has the following limitations and is required to be considered in further future studies. Firstly, there may be other factors and concepts that may influence innovation resistance and diffusion of media technological innovation to organization. With the result of this study only, there is a limit to fully explain the internal resistance and internal diffusion of inner members when media companies introduce new media innovation technologies into their organizations. Secondly, there was a limit for surveyees to fully understand the concept of ICT-based technological innovation through only survey papers. In addition, there were many responses focused on specific answers, such as organizational complacency, innovation resistance, innovation diffusion, as the period of organizational restructuring and questionnaire survey were synchronized. Thus, there might be controversial on reliability and validity although they are verified.

Considering above limitations, further research is necessary to conduct in-depth interview or long-term observation rather than questionnaire survey and to concentrate on journalists and program directors who are positioned at the beginning of value chain in media industry. Especially, as they are regarded themselves as professionals, it might be possible to develop new framework to apply to other professional group and to find out reliable solutions about innovation resistance if responses and the cause of adopting new media technological innovation are found.

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# A Study on Innovation Resistance to Home IoT Provided by Telecom Operators

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## ABSTRACT

Innovations such as Home IoT causes changes to the consumers. And the consumers' resistance is a natural response to these changes. As such, it is necessary to confirm the reason behind consumer resistance to these changes and make continued efforts for improvement in order to revitalize home IoT services.

The purpose of this study focuses on the MNO (Mobile Network Operator) Home IoT service. how it influences consumer's innovation resistance to present a research model and conduct substantial analysis based on existing precedent studies in regard to innovation resistance models and elaboration-likelihood models and its involvement. Considering the characteristics of Home IoT being an applied service via connection based on data, the writer observed whether the user involvement of the data collected from a Home IoT device moderates between the recognized characteristics of innovation and innovation resistance.

As a result, it is shown relative advantages and current smartphone app attitude has a negative effect on innovation resistance whereas complexity and financial risk have a positive effect on innovation resistance. Also, innovation resistance is seen to have a mediate role on the relationship between the recognized innovation characteristics and intention of acceptance. Moreover, the user's involvement on data influences the effects that financial risk has on innovation resistance, moderates the influences that improved innovation expectations have on innovation resistance, and has negative effects. Based on these findings, whether or not 'data retrieved from IoT devices are useful to consumers' can be an important factor of consideration for MNOs that have introduced Home IoT service models.

This study may contribute to the continued improvement of the reason behind consumer reluctance for Home IoT service, and may furthermore be of assistance to the company product planner when deciding the future Home IoT device to launch and establishing a strategy.

## KEYWORD

Home IoT, innovation resistance model, elaboration-likelihood model, involvement

## I. INTRODUCTION

### *1. Background*

Recently, global corporations are showing increased interest in IoT while many companies are considering IoT as the next generation growth engine. In particular, the Home IoT area, which has been referred to as an existing smart home, is a highly competitive area for global companies, manufacturers and telecom operators. Domestic telecommunication carriers launched 166 IoT products, of which 67%, 111 are focused on Home IoT services (Electronic Times 29 SEP 2016).

However, despite the MNOs aggressive market invasion and positive expectations of high growth in the Home IoT market, there has been some delays in the revitalizations of this market and the consumers' actual willingness to pay for these services are very low (Consumer Insight 20 SEP 2016).

It is necessary to make the effort to indicate the cause of the consumers' unacceptance towards Home IoT and fix the problems in order to revitalize Home IoT. Home IoT is an applied service which is enabled via connection with the data produced from a product (Cho, 2015). Also, Porter and Heppelmann (2014) stated that the engine that leads the era of new competition will be the product's extended functions and produced information while emphasizing that it is required for the companies to assess which function can provide true value to the customers beyond the price among the various IoT products. As such, this study will take a look at the real reasons as to why the consumers show unacceptance towards these services based on the characteristics of Home IoT.

### *2. Purpose*

Home IoT service is still in its initial phase making it less popular. Consumer Insight conducted a survey in April of 2016 stating that 17 percent of the population is aware of Home IoT service while 33 percent has heard of it. The remaining 50 percent is unaware of Home IoT (Consumer Insight 20 SEP 2016).

There are deviations on how many users use each Home IoT device that has been launched during the same period. For company A's Home IoT devices, the actual subscribers may differ up to 355 times more than another product even though they were launched during the same period. Even when the purchase price of Home IoT devices was similar, the number of subscribers differ by 142 times (Company 'A' internal data, SEP 2016). Although there might be external factors such as corporate promotion, it can also be said that there are internal factors of Home IoT service that influence the unacceptance of consumers.

Therefore, this study deduces the following research problems to figure out the reasons behind the disparities within consumer

acceptance, willingness to pay, and number of subscribers regarding Home IoT services:

**Problem 1.** What is the reason for the consumer unacceptance of Home IoT service despite companies' aggressive market intervention and positive expectations?

As Home IoT service is an applied service that requires connection based on data, the following research problem has been deduced to figure out if the data that comes from the Home IoT device can explain the deviation among the number of subscribers (Porter and Heppelmann 2014), (Cho, 2015).

**Problem 2.** Does the user involvement in the data that is provided by the Home IoT device influence the acceptance towards Home IoT services?

This study aims to contribute to the continued improvement of the reason behind consumer reluctance for Home IoT service, and furthermore to be of assistance to the company product planner in an attempt to select the future Home IoT devices to launch and to establish strategies.

### **3. Scope and Methodology**

Independent variables such as relative advantages, complexity, financial risk, improved innovation expectation, innovation tendency, and existing smartphone app attitude were selected based on the innovation resistance model through precedent studies. Also, the mediator variable was innovation resistance which is the main variable of the innovation resistance model while the dependent variable was the intent to accept. Furthermore, with the precedent studies on the elaboration-likelihood model and involvement, the research model was established by adding the user's involvement regarding data retrievable from the Home IoT device as the moderator variable while conducting substantial research through surveys.

This study addresses the background and purpose in Chapter 1 in the introduction. Chapter 2 starts with the introduction to Home IoT then considers the initial and moderator factors which might influence the acceptance intention of Home IoT based on precedent studies on innovation resistance theory, elaboration-likelihood model, and involvement. Chapter 3 designs the research model and sets the hypothesis based on the deduced variables through precedent studies. Chapter 4 addresses the operational definition and analysis method which was used for the study. Chapter 5 conducts an analysis of the data and verifies the hypothesis based on the set hypothesis and collected samples. Lastly, Chapter 6 discusses this study's results and theoretical meaning while addressing the limitations and future research direction.

## **II. Theoretical Background**

### **1. Home IoT Introduction**

#### **1.1 Definition**

Home IoT is a technology and service in which the home appliances and/or home equipment with the function of the Internet of Things (IoT) autonomously producing information and connecting with other things or people to increase the quality of residential life of the user through a certain level of automation (Son and Park 2015).

Lee (2015) state that smart home is the automation of separate devices in the home then evolved into the connection of home devices, and is now defined as the home devices becoming smarter and connected leading to the smart home. Porter and Heppelmann (2014) states that the IoT product is a Smart Connected Product, and is changing into a Smart Connected Product thereby changing the ways of company's competition.

Cho (2015) states that a true IoT service is a connected, operated, and integrated service while mentioning that devices with merely adding the internet connection only makes it a Smart Thing. In order to understand the new business that represents IoT one must discern between Smart Things and IoT, and should emphasize the importance of clearly comprehending that this is a data-oriented service and not a technology provided by a certain device.

This study limits the research subject to MNO Home IoT, and the products which were launched by the local MNOs in cooperation with the OEMs.

#### **1.2 Home IoT market status and projections**

The Home IoT sector has not long been defined as which product will be the hub. But with Nest's Thermostat in 2014, approximately 3.2 million units were sold while Apple responded by launching the Ecobee3 that supports the Apple Home Kit temperature adjuster, thereby some suggest that the smart temperature adjuster is the first Killer Application of Home IoT at least in the US (Lee 2015).

Kang (2015) predicted that the smart home assistant will be the 'iPhone' of the smart home market. The first to try the smart home assistant was Echo of Amazon while the predictions were that this would bring about an equal level of impact to the market just like the iPhone.

Local MNOs are also actively partaking in the global IoT standard competition. SKT selects 'Laura' while KT and LGU+ chooses 'NB-IoT' try to secure the initiative (Financial Times 17 OCT 2016).

#### **1.3 Main factors of Home IoT**

Selecting which collection of Home IoT devices to use among the various functions and characteristics is very important. Compared to existing products, the potential capacity and scope of functions could drastically expand for Home IoT products thereby luring companies to cram in as many functions as possible into the product. But simply adding a lot of new features does not increase the value offered to customers to cover the costs and make a profit (Porter and Heppelmann 2014).

Cho (2015) stated that in the perspective of User eXperience, the era of IoT is not all that rosy. It is due to the fact that IoT service having various devices connected will be too complex for the user and difficult to understand. and so is Home IoT. Home IoT devices' value is provided to the user by creating an environment where the user can conveniently reside in the comfort of one's own home without much effort. However, the user has to learn how to use a new smartphone app and how to operate the newly installed Home IoT devices which may not be such an enjoyable experience. One of the biggest obstacles to the proliferation of Home IoT is privacy and security issues. Wearable devices enable to track not only the user's location, but also the biological data such as heart rate which could have devastating consequences should such information be leaked. The security level of IoT devices compared to PCs is extremely weaker and is assessed to be vulnerable to hacking (Chosun Times 24 OCT 2016).

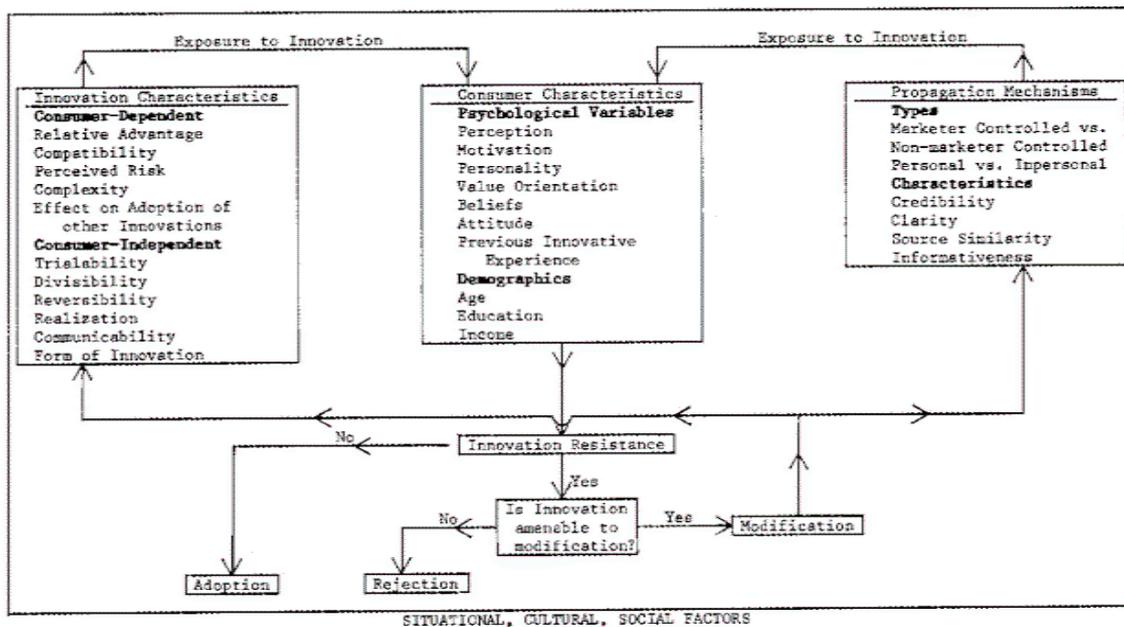
**2. Innovation resistance model**

Rogers (2010) stated that innovation refers to idea, things, or practices that an individual or other adoptive unit perceives as new. The most significant factor in the diffusion of innovation are innovation, communication channels, time and social system, but innovation characteristics have the greatest explanatory power. Technology acceptance theory predicts the acceptability of new technology and is the most effective theoretical framework which has been applied in various studies such as serving as a theoretical frame for innovation acceptance studies (Davis 1989, Kim 2010). Innovation proliferation theory and technology acceptance theory have deduced and substantially verified various adopting factors, but have remised the reason as to why members of society would refuse or neglect innovation (Jang and Park 2010).

Ram (1987) asserts that all innovation is good for the consumer and that it is biased to categorize late adopters of innovation as innovation acceptance disabled. Ram and Sheth have proven that most companies face difficulties in high fail rates with new products and/or services while only a small number of products succeed where the major factor of failure is that companies face the consumers' innovation resistance (Ram and Sheth 1989).

Innovation resistance was first addressed by Sheth and Stellner (1979), and Ram (1987) presented the innovation resistance model based on the concept of Sheth. Ram defines innovation resistance as the consumers' resistance against the changes caused by innovation.

Rogers (2010) said that acceptance and proliferation occurs when innovation resistance is overcome, and if the consumer resistance is high, then the adoption period gets delayed or proliferation may never happen at all.



<Figure 1> A model of Innovation Resistance

The figure 1 above illustrates that innovation characteristics recognized as Ram's innovation resistance model deduces the prediction variables that induce user resistance against innovation from the innovation adoption decision factor of the innovation proliferation theory. The prediction variables of innovation resistance are classified as largely recognized innovation characteristics, consumer characteristics, and proliferation mechanisms (Ram 1987). Should innovation resistance exist while there is no flexibility for modification of the innovation, then the consumers will refuse the innovation. If there is an innovation resistance, the consumer refuses to innovate if the innovation is not amendable (Ram 1987).

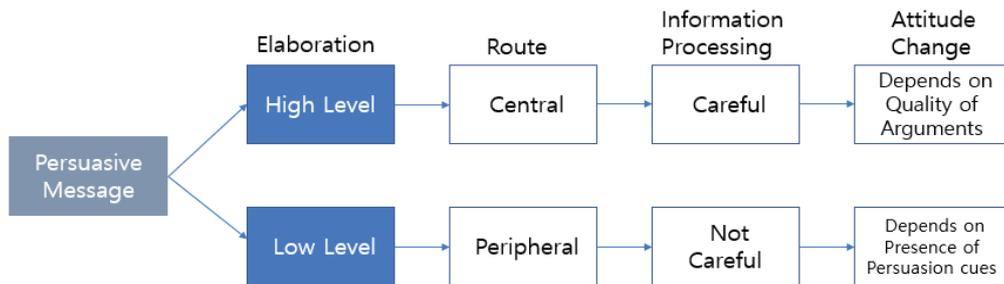
Shin (2015) studied the user innovation resistance of wrist wearable devices based on the innovation resistance model to confirm that relative advantages, improved innovation expectations, complexity, financial risk, and physical risk of the recognized characteristics had valid influence on innovation resistance. Also, among the factors of consumer characteristics, it was confirmed that innovation resistance and the current analog watch product attitude had valid influence on innovation resistance. Yun and Kim (2014) confirmed that the deciding factor that influences the innovation resistance are the complexities of consumer's electronic book acceptance and the existing paper book product attitude while innovation resistance has a negative effect on acceptance intention.

Home IoT service is showing a low subscriber growth, unlike the expectation that demand will increase rapidly, and it relies on the increase of subscribers through promotions and bundling due to consumer's low-cost payment intention. Home IoT is able to find various consumer resistance factors in the initial introduction, and companies should conduct studies based on the innovation resistance model to verify the fundamental cause that could minimize consumer resistance, and apply this to the product planning.

### 3. Elaboration Likelihood Model

The elaboration likelihood model was proposed by Petty and Cacioppo, which is a model with dual paths of persuasion where the assumption is that the persuasion message is processed via two routes including the central route and the peripheral route (Cacioppo and Petty 1984, Petty and Cacioppo 1986). The persuasion message process route is determined by factors such as the message's quality or involvement (Petty and Cacioppo 1990).

If the proposed message is an important issue for the audience, for example, the message is highly involved or the quality of the presented message is high, message processing occurs using the central route. To process the message via the central route, there should be a motive and capability to process the presented message cognitively. If the attitude changes after processing the persuasion message by the central route, this attitude is more stable than when the persuasion message is processed by the peripheral route. (Cacioppo and Petty 1984, Petty and Cacioppo 1986).



<Figure 2> Elaboration Likelihood Model Process

Thus, if the elaboration likelihood increases due to the level of cognitive effort in the central route, the elaboration likelihood in the peripheral route will decrease (Donggi Kim, Soohyun Bae et al. 1993).

Bhattacharjee and Sandord (2006) divided the acceptance intention formation process of IT systems into central routes and peripheral routes where the user with elaboration motives and high capabilities is more influenced by the central route, and found that the attitude formed via the central route is more stable and sustainable. In his study of the initial reliability of mobile banking users, Zhou(2012) found that self-efficacy acts as a moderator when processing information via the central route and peripheral route.

The process routes of these persuasion messages are determined by the quality or involvement of the persuasion message. In the case of the Home IoT service, one of the main factors that determines the processing route of the message is to determine which route is processed by the central route and the peripheral route depending on the refinement possibility of the consumer, this study aims to focus on the involvement.

### 4. Involvement

For involvement, Krugman (1977) introduced the concept of consumer behavior and applied it to advertisement influences studies which later came about many similar studies. Antil (1984) stated that involvement means the personal importance or level of interest perceived by certain stimulations in certain situations. Also, involvement is a main factor in determining the persuasion message process route in an elaborate likelihood model, and if the involvement is high toward the subject the message is processed via the central route whereas the message will be processed via the peripheral route if it is low (Petty and Cacioppo 1990).

Involvement has been spotlighted as an important variable that moderates the information process effect of persuasive communication in the consumer behavior research field (Antil 1984, Hong 2008). Especially, in the elaboration likelihood model, it is asserted that there is a higher probability of prudent logical deduction when there is more personal involvement or higher importance of a certain product or issue. Thus, as the involvement is higher, the persuasion message gets processed via the central route which leads to cognitive effort in evaluating the persuasion message (Hong 2008).

Gwak (2008) studied the product involvement impact within the internet purchase decision process, and found that the levels of purchase experience, recognized risk, and recognized price would differ based on the product's level or type of involvement. Hong (2008) found that personal involvement had a moderator effect during a study on the ERP information system's usage intent.

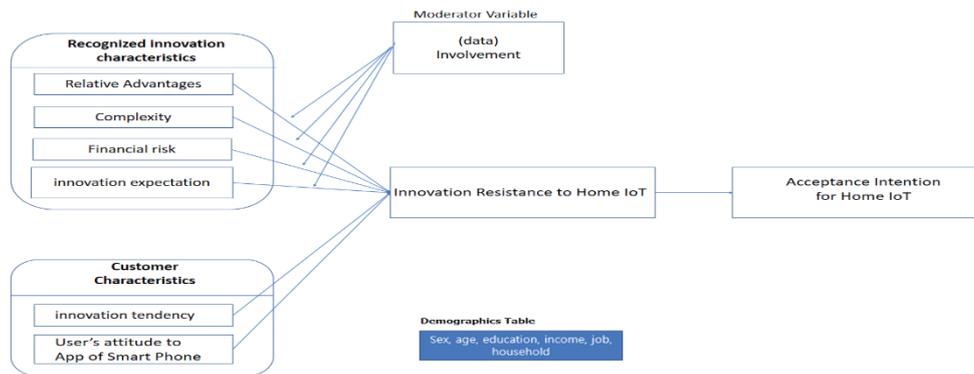
Since Home IoT is an applied service that requires data for connection, the data that comes from the Home IoT device should be able to attract interest of the user. Therefore, this study attempts to see the most important factor in Home IoT, the impact of the user involvement in regard to the data collected from the Home IoT device on the consumer's Home IoT process route and innovation resistance.

## III. Research model and hypothesis

### 1. Research model

This study composed a research model with variables verified in precedent studies based on the innovation resistance model to observe the factors that may influence the innovation resistance in the process of consumer acceptance of Home IoT service. Furthermore, the following research model was established by adding the moderator variable to identify the influences of user

involvement regarding the data from the Home IoT device on the consumer innovation resistance.



<Figure 3> The research model of this study

## 2. Hypothesis

Based on the presented research model, this study has set the following hypothesis in regard to the innovation resistance, recognized innovation characteristics, and consumer characteristics that influence the acceptance as well as the moderator variables that influence the recognized innovation characteristics.

### 2.1 Recognized innovation characteristics

Recognized innovation characteristics displays the technical characteristics of innovation which is categorized into consumer dependent variables and consumer independent variables. Consumer-dependent variables are variables that can be changed by consumers, and consumer-independent variables are the same regardless of consumer differences (Ram 1987, Ram and Sheth 1989). Since the research subject of innovation resistance are mostly consumers, many studies have observed what the factors influence the innovation resistance of consumers focusing on consumer dependent variables (Yoo and Lee 1994) (Yoon, Kim et al. 2014). In addition, this study excluded the consumer independent variables such as ‘test likelihood’ to analyze how the user involvement regarding the data provided by the Home IoT device influences the relationship between the recognized innovation characteristics and innovation resistance.

#### 2.1.1 Relative advantage

Schiffman and Kanuk (1991) stated that if the innovation product did not measure up to the product that the consumer was going to exchange, or was less attractive than the current product, it would lead to innovation resistance. Yoon and Kim (2014) verified that the higher the relative advantage, the lower the innovation resistance according to the study regarding electronics book’s acceptance process. This study deduced the following hypothesis predicting that relative advantage will have a valid influence on innovation resistance.

H1-1. The relative advantage of consumer innovation characteristics will have a negative (-) impact on innovation resistance.

#### 2.1.2 Complexity

Yoon and Kim (2014) verified the proposition of Schiffman and Kanuk (1991) that the higher the innovation complexity, the greater the resistance will be towards innovation. Shin (2015) found that complexity had a positive effect on innovation resistance for wrist wearable devices. This study deduced the following hypothesis by assessing that complexity will have a valid influence on innovation resistance.

H1-2. The complexity of consumers’ innovation characteristics will have a positive (+) impact on innovation resistance.

#### 2.1.3 Financial risk

Ram and Sheth (1989) categorized recognized risks into physical risks, economical risks, functional risks, and social risks while Shin and Lee (2016) found that of the innovation characteristic factors, the higher the financial risk, the greater the innovation resistance (Shin and Lee 2016). This study deduced the following hypothesis by assessing that financial risk will have a valid influence on innovation resistance.

H1-3. The financial risk, which is the innovation characteristic of the consumer, will have a positive (+) impact on the innovation resistance.

#### 2.1.4 Improved innovation expectations

Schiffman and Kanuk (1991) stated that when the consumer has confidence and higher expectations of a soon to be launched product, the greater the innovation resistance becomes resulting in a positive effect. However, Shin (2015) found in the previous study that the improved innovation expectations will have a negative effect on the innovation resistance for the wrist wearable device. This study deduced the following hypothesis by assessing that improved innovation expectations will have a valid influence on innovation resistance. Since the previous studies suggest that improved innovation expectations have different effects towards innovation resistance, this study aims to find what kind of influence it will have when there are valid influences.

H1-4. Improved innovation expectations, which are consumer innovations, will have a positive (+) impact on innovation resistance.

## **2.2 Consumer characteristics**

The innovation resistance model's consumer characteristics are product attributes evaluation, motivation, uniqueness, conviction, attitude, attitude towards previous products, and population statistical characteristic factors. In regard to the product attributes evaluation which is a consumer characteristic factor, Ram (1987) stated that if the consumer had an unfavorable assessment of the product attributes, there would be resistance against innovation. Whereas for motivation, if the consumer is satisfied with the previous product to the extent where they do not feel the need for innovation or the willingness to accept, there will be resistance against innovation.

Especially, most Home IoT service involve using the service after confirming various information through a smartphone app once the Home IoT device is installed. Therefore, it is necessary to confirm the attitude of the user in regard to the current smartphone app. Kim and Han (2011) have confirmed that there are many cases where the consumers downloaded the app but did not actually use it according to a report in the Localytics.

This study focuses on the innovation tendency which is a verified variable of the precedent studies and the attitude towards previous products to observe the consumer characteristic's influence on innovation resistance.

### **2.2.1 Innovation tendency**

Ram (1987) stated that people who support change have lower innovation resistance than those who do not, and also asserted that the influence on innovation resistance may differ depending on the consumer's attitude or tendency. Shin and Lee (2016) found how the consumer's innovation tendency influences the innovation resistance against wrist wearable device. This study deduced the following hypothesis by assessing that innovation tendency will have a valid influence on innovation resistance.

H1-5. Innovation tendency, which is a consumer characteristic, will have a negative impact (+) on innovation resistance.

### **2.2.2 Attitude towards current smartphone apps**

Yun and Kim (2014) found that the high the satisfaction and frequent use of current products, the greater the innovation resistance while Shin and Lee (2016) found that the current analog watch product attitude has positive influence on the innovation resistance of wrist wearable devices. These precedent studies have shown that the attitude towards current products have a valid influence on innovation resistance, but for MNO Home IoT service, a variety of services are being launched leading to difficulty in measuring the influence of the attitude towards current products. However, with an exception of a few Home IoT services, most require a smartphone application to be used together with the Home IoT service thus it is assumed that the more positive the consumer is regarding attitude towards smartphone apps, it is less likely to have any complaints with the service. As such, this study deduced the following hypothesis by assessing that the attitude towards current smartphone apps will have a valid influence on innovation resistance.

H1-6. Existing smartphone app attitudes, which are consumers' characteristics, will have a negative impact (-) on innovation resistance.

### **2.2.3 Innovation resistance**

Rogers (2010) stated that acceptance and proliferation occurs when innovation resistance is overcome, but if the resistance is strong, then the adoption period gets delayed or proliferation does not happen. Ram (1987) states that consumer innovation acceptance occurs when innovation resistance does not exist through the innovation resistance model (Ram 1987). Shin and Lee (2016) found that the lower the consumer innovation resistance, the acceptance intention increases. Ram (1987) asserted that consumers' resistance is high and that the adoption period is delayed or does not spread and disappears in the market. In this study, the following hypothesis is derived.

H1-7. Innovation resistance regarding Home IoT service will have a negative impact (-) on acceptance intention through mediation of innovation characteristics and consumer characteristics.

## **2.3 moderator variables**

Cho (2015) defines Home IoT as an applied service which is enabled via connection with the data produced from a product. Porter and Heppelmann (2014) suggested that the information produced from the extended functions and products of smart connected products are indeed the engine that will lead the new competition era. As such, data is an essential factor of Home IoT, and providing useful data to consumers can be seen as a basic element in providing value to the consumers. Therefore, in the perspective of 'user necessity', this study established the hypothesis that providing useful, important, and interesting data for the consumers via Home IoT devices will influence the innovation resistance and acceptance intention of the consumer. Also, this study attempts to conduct analysis by using the consumer involvement in regard to data.

### **2.3.1 Involvement**

Petty and Caccioppo (1984, 1990) stated that in the elaboration likelihood model, the higher the personal relevance or importance of a certain product or issue, the likelier it will be for a prudent logical inference. When the involvement is high, the cognitive effort to evaluate the related assertion tend to be increased, and as a result, the attitude becomes more relevant to the cognitive information processing central route. When the involvement is low, the attitude is determined as a result of the peripheral route, which is the

information processing process triggered by simple cues, and the influence of the cognitive information processing is reduced. When using the central route, the attitude change is relatively continuous and easy to influence behavior. Providing data that is required by a consumer in Home IoT is an importance factor for providing value to the consumer, and the consumer involvement on data may influence the processing route (central route, peripheral route) regarding Home IoT. This study deduced the following hypothesis by assessing that the consumer involvement regarding data collected from Home IoT devices will have a valid influence on the relationship between recognized innovation characteristics and innovation resistance.

H2-1. The impact of relative advantage on innovation resistance will depend on the involvement of the data collected on the Home IoT device.

H2-2. The impact of complexity on innovation resistance will depend on the involvement of data collected on Home IoT devices.

H2-3. The impact of financial risk on innovation resistance will depend on the involvement of data collected on Home IoT devices.

H2-4. The impact of improved innovation expectations on innovation resistance will depend on the involvement of data collected on Home IoT devices.

#### IV. RESEARCH METHOD

##### 1. operational definition and measurement list of research variables

This study redefines the substantiated concepts of precedent studies according to the findings of this study, and manipulated the variables to measure each variable. Relative advantages, complexity, financial risk, improved innovation expectations, innovation tendencies, and the attitude towards current smartphone apps are all independent variables while innovation resistance is the mediator variable and acceptance intention the dependent variable. In addition, the involvement designated as the moderator variable to find whether the degree of the user’s relevance to the data collected from the Home IoT device has a moderator effect within the relationship between recognized innovation characteristics and innovation resistance.

[Table 1. operational definition of research variable]

Variable name	operational definition	related research
(Data) Involvement	Awareness of personal involvement level of collected data from Home IoT devices	Antil(1984), Zaichkowsky(1985), Soon-Geun Hong(2008)
Relative Advantages	Advantage of Home IoT Service subscriptions	Ram(1987), Pil-Hwa Yoo(1994) Jae-Gwon Shin & Sang-Woo Lee(2016)
Complexity	Complexity of service understanding and execution (if easy to use)	Ram(1987), Jae-Gwon Shin & Sang-Woo Lee(2016)
Financial risk	financial risk level of Home IoT service subscriptions	Ram(1987), Ram & Sheth(1989)
Improved innovation expectations	expectation of better Home IoT service performance	Ram(1987), Pil-Hwa Yoo(1994) Jae-Gwon Shin & Sang-Woo Lee(2016)
innovation tendency	preference level of new products & services and confidence in use	Young-Ho chang(2010) Jae-Gwon Shin & Sang-Woo Lee(2016)
Existing smartphone app attitude	satisfaction and usage level of existing smartphone apps	Ram(1987), Pil-Hwa Yoo(1994) Jae-Gwon Shin & Sang-Woo Lee(2016)
Home IoT innovation resistance	Emotional & behavioral resistance of change in Home IoT Service subscriptions	Ram(1987), Ram & Sheth(1989) Su-Kyung Yoon (2014)
Home IoT acceptance intention	intention of accepting Home IoT services	Ram(1987), Ram & Sheth(1989) Su-Kyung Yoon (2014)

Also, the items of each variable are cited in the items that have proved to be reliable and valid in the previous study, and the study composed a survey with 38 questions tailored to the context of Home IoT service. This survey has explanatory material in the beginning which includes brief explanations of the research purpose and references when answering questions along with information to help understand details of the Home IoT services provided by MNOs such as IoT plugin function, fees, usage, and collected data.

Excluding some portions of the survey (population statistics, Home IoT recognition & usage experience, devices, data of interest, desired devices in the future), the rest of the items are scored a 7 (strongly agrees) if one agrees with the item, and the score is 1 (strongly disagree) if one does not agree on the Likert 7 point-scale.

##### 2. Data collection

This study identifies the factors that may influence the consumer’s Home IoT acceptance intention based on the innovation resistance model, and collects data via surveys to identify if the user involvement in data provided by Home IoT devices influences innovation resistance.

The pre-survey was done by conducting the 1<sup>st</sup> survey with 55 people through convenience sampling, and some portions of the

survey were refined such as questions difficult to understand as well as parts where the reliability and validity were not verified. The 2<sup>nd</sup> survey was conducted through Insight, a professional online survey company, against people at the of 20~60 years old. The survey was conducted for 6 days between November 23, 2016 and November 28, 2016 and collected a total of 128 surveys.

### 3. Analysis method

This study conducted analysis with the statistics analysis package SPSS 23 and Smart PLS to verify the research hypothesis. Based on the 128 surveys collected from the surveying, sample characteristics were observed while factor analysis was conducted to analyze the measurement items' reliability and validity, and identified the Cronbach Alpha value. In addition, correlation analysis and multicollinearity analysis were conducted to identify the relevance among variables. Henceforth, analysis was conducted with Smartpls based on the structural equation model to verify the hypothesis.

## V. Data analysis and hypothesis verification

### 1. Sample characteristics

#### 1.1 Demographic characteristics

The demographic characteristics of the 128 samples from the survey are classified as in [Table 2].

[Table 2. demographic characteristics of survey responders]

categories	number of respondents	rate	
sex	male	67	52.3%
	female	61	47.7%
	<b>Total</b>	<b>128</b>	<b>100%</b>
Age	20-29 years old	26	20.3%
	30-39 years old	30	23.4%
	40-49 years old	37	28.9%
	50-59 years old	35	27.3%
	<b>Total</b>	<b>128</b>	<b>100%</b>
Education	high school	18	14.1%
	Bachelor's degree	89	69.5%
	Master's degree	17	13.3%
	Ph.D /M.D	4	3.1%
	<b>Total</b>	<b>128</b>	<b>100%</b>
Income	Student	13	10.2%
	Office Worker	62	48.4%
	Technical Official	5	3.9%
	Practitioner	14	10.9%
	Sales & Service Worker	8	6.3%
	Full-time Housemaker	13	10.2%
	Other	9	7.0%
	Unemployed	4	3.1%
	<b>Total</b>	<b>128</b>	<b>100%</b>
job	less than \$2000	22	17.2%
	\$2000-3000	25	19.5%
	\$3000-4000	26	20.3%
	\$4000-5000	19	14.8%
	More than \$5000	27	21.1%
	Not income	9	7.0%
<b>Total</b>	<b>128</b>	<b>100%</b>	
household	one-person household	22	17.2%
	two-person household	20	15.6%
	three-person household	33	25.8%
	More than four-person household	53	41.4%
	<b>Total</b>	<b>128</b>	<b>100%</b>

#### 1.2 Home IoT usage experience and awareness

The awareness and usage experience of Home IoT among the 128 samples from the survey are classified in [Table 3]. Those who had Home IoT usage experience are 6.3% while the remaining 93.8% did not have Home IoT experience, and these results can be estimated because the survey excluded those who were currently using Home IoT service at the time of the survey.

[Table 3. Home IoT awareness and usage experience status]

	categories	number of respondents	rate
Awareness	very aware	41	32.0%
	somewhat aware	69	53.9%
	not at all aware	18	14.1%
	Total	128	100%
Usage Experience	Yes	8	6.3%
	No	120	93.8%
	Total	128	100%

## 2. Measurement model verification

### 2.1 Factor analysis and reliability verification

This study measured the reliability and validity of the measurement tool to verify the measurement model. First, the factor analysis on the 32-question regarding the 9 variables is shown as in [Table 4] as a result of the factor analysis on the nine variables, and question 3 was removed due to the factor loading having less than 0.7. Henceforth, the 31 questions underwent the Cronbach Alpha that indicates the reliability of the measurement tool and the results are as shown in [Table 5]. All Cronbach Alpha values of variable measurements were over 0.7 to confirm that the reliability is verified.

[Table 4. Factor analysis results]

	RB	COM	MON	FUT	INO	PHONE	RES	INT
RB1	0.919							
RB2	0.936							
RB3	0.934							
RB4	0.890							
COM1		0.841						
COM2		0.854						
COM3		0.851						
MON1			0.909					
MON2			0.919					
MON3			0.842					
FUT1				0.950				
FUT2				0.958				
INO1					0.851			
INO2					0.854			
INO3					0.840			
INO4					0.745			
PHONE1						0.927		
PHONE2						0.901		
PHONE3						0.908		
RES1							0.864	
RES2							0.895	
RES3							0.751	
RES4							0.887	
INT1								0.823
INT2								0.923
INT3								0.900

[Table 5. Reliability analysis results]

Measurement variable	Number of items	Cronbach Alpha
(Data) Involvement	5	0.958
Relative Advantages	4	0.938
Complexity	3	0.809
Financial risk	3	0.872
Improved innovation expectations	2	0.901
innovation tendency	4	0.842
Existing smartphone app attitude	3	0.900
Home IoT innovation resistance	4	0.872
Home IoT acceptance intention	3	0.858

## 2.2 Convergent validity analysis

The measurement list was confirmed in [Table 6] including the factor loading, t-value of factor loading, averaged variance extracted, and reliability index to conduct the convergent validity analysis. Each variable's averaged variance extracted was greater than 0.5, factor loading greater than 0.7, composite reliability and Cronbach Alpha greater than 0.7, confirming the convergent validity (Fornell and Larcker 1981, Gefen, Straub et al. 2000).

[Table 6. Convergent validity verification results]

Measuring Variables	measurement items	factor analysis	t-value	AVE	Composite Reliability	Cronbach Alpha
Relative Advantages	RB1	0.920	57.230	0.847	0.956	0.939
	RB2	0.937	62.630			
	RB3	0.934	69.233			
	RB4	0.891	32.085			
Complexity	COM1	0.842	21.803	0.721	0.885	0.808
	COM2	0.855	18.322			
	COM3	0.851	26.425			
Financial risk	MON1	0.910	33.588	0.794	0.920	0.871
	MON2	0.920	57.272			
	MON3	0.842	18.931			
Improved innovation expectations	FUT1	0.950	46.547	0.910	0.953	0.901
	FUT2	0.958	45.038			
Innovation tendency	INO1	0.851	25.669	0.679	0.894	0.841
	INO2	0.855	27.730			
	INO3	0.840	18.630			
	INO4	0.746	12.485			
Existing smartphone app attitude	PHONE1	0.927	48.296	0.832	0.937	0.899
	PHONE2	0.901	28.036			
	PHONE3	0.909	39.635			
Innovation resistance	RES1	0.864	30.756	0.725	0.913	0.872
	RES2	0.895	54.199			
	RES3	0.751	12.931			
	RES4	0.888	34.459			
Acceptance intention	INT1	0.824	12.873	0.781	0.914	0.858
	INT2	0.924	37.251			
	INT3	0.901	43.433			

2.3 Discriminant validity and multicollinearity analysis

Correlation analysis was conducted to confirm the discriminant validity among variables. It can be said that the discriminant validity is present if the correlation coefficient is low among independent variables, and the correlation coefficient satisfies the criteria if it is less than 0.6. The correlation coefficient among independent variables can be confirmed on [Table 7].

[Table 7. Discriminant validity analysis results among independent variables]

Categories	MRB	MCOM	MMON	MFUT	MINO	MPHONE
MRB	1					
MCOM	-.317**	1				
MMON	-.469**	.203*	1			
MFUT	.450**	-.224*	-.061	1		
MINO	.292**	-.484**	-.158	.261**	1	
MPHONE	.296**	-.435**	-.075	.255**	.454**	1

When using PLS to analyze, the square root value of the averaged variance extracted must be greater than 0.7 as shown in [Table 8], and if the square root value of the averaged variance extracted is greater than another variable’s correlation coefficient, it can mean that the discriminant validity is present. But the correlation coefficient of some variables in [Table 8] are greater than 0.6, so additional multicollinearity was conducted and the results are as shown in [Table 9].

[Table 8. Multicollinearity analysis results among configuration concept]

Categories	COM	FUT	INO	INT	MON	PHONE	RB	RES
COM	0.849							
FUT	-0.240	0.953						
INO	-0.503	0.264	0.824					
INT	-0.471	0.282	0.496	0.883				
MON	0.199	-0.078	-0.165	-0.631	0.891			
PHONE	-0.448	0.256	0.460	0.298	-0.077	0.912		
RB	-0.337	0.451	0.292	0.541	-0.483	0.293	0.920	
RES	0.545	-0.315	-0.464	-0.858	0.576	-0.418	-0.601	0.851

Multicollinearity means that there is a high correlation among two or more independent variables used in the multiple regression analysis. To identify multicollinearity, generally if the tolerance is greater than 0.1 or if the VIF (Variance Inflation Factor) is smaller than 10, it means that the multicollinearity is not as severe. (Myungchun Lee and Yohan Kim 2014).

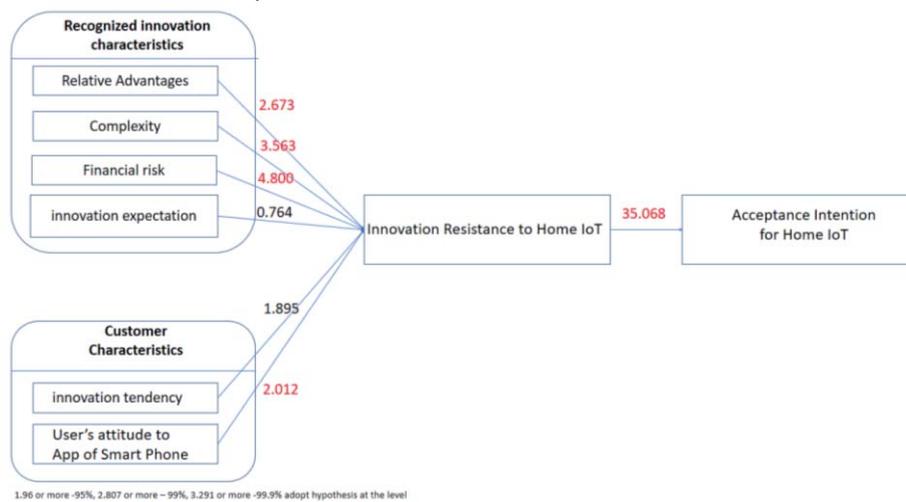
[Table 9. Multicollinearity results]

measuring variables	Tolerance	VIF
MRB	0.569	1.759
MCOM	0.682	1.466
MMON	0.739	1.353
MFUT	0.744	1.343
MINO	0.675	1.481
MPHONE	0.707	1.415

### 3. Hypotheses verification and results

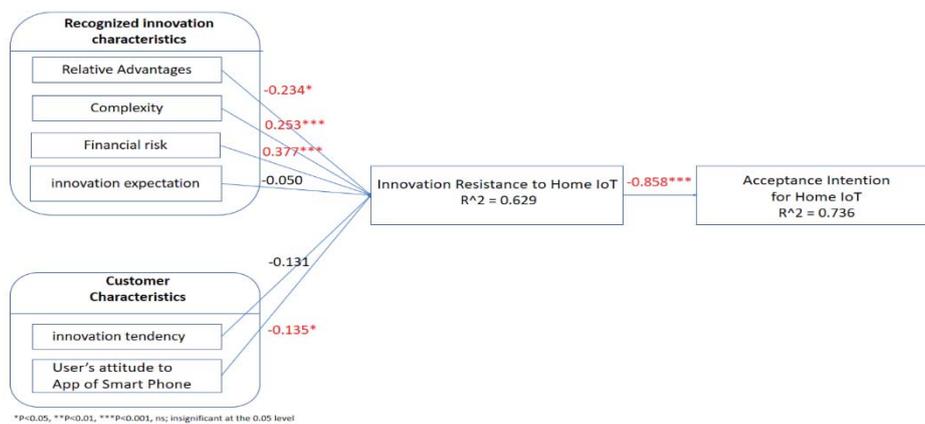
#### 3.1. Innovation resistance model Hypotheses verification

After completing verification of the measurement model, verification for the structural equation model was conducted with the Smart PLS program. Bootstrapping function of PLS was used to compose 1,000 samples and checked the t-value to assess if the hypothesis possesses statistical meaning. The criterion of the t-value is 1.960(p<0.05), 2.807(p<0.01), 3.291(p<<0.001). For the result of the hypothesis verification, 5 out of 7 hypotheses regarding recognized innovation characteristics, consumer characteristics and Home IoT innovation resistance were adopted.



[Figure 4. T-value of individual routes for hypothesis verification]

The individual route's path coefficient and research model's explanation power can be seen in [Figure 5], where it is shown that financial risk is the most influential factor to Home IoT innovation resistance.



[Figure 5. Research model analysis result]

### 3.2 Moderator variable hypothesis verification

Innovation characteristics of user involvement in data collected from Home IoT devices and hypothesis test for moderating role in Home IoT innovation resistance were conducted using a test method to measure the magnitude of the moderator effect. The moderator effect can be calculated with the following equation.

$$\text{Moderator effect} = [R_2^2 - R_1^2] / [1 - R_2^2]$$

$R_1^2 =$  explanation power of main effect models  
 $R_2^2 =$  explanation power of interacting models

[Figure 6. Moderator effect Size]

According to the previous study results, if the moderator effect's size is greater than 0.02 then the moderator effect is rather small, but if greater than 0.15 it has medium effect, and if it is greater than 0.35 it has great effect (Cohen 1992, Tae-Yeop Yang 2015). Analyzed results are shown in [Table 10].

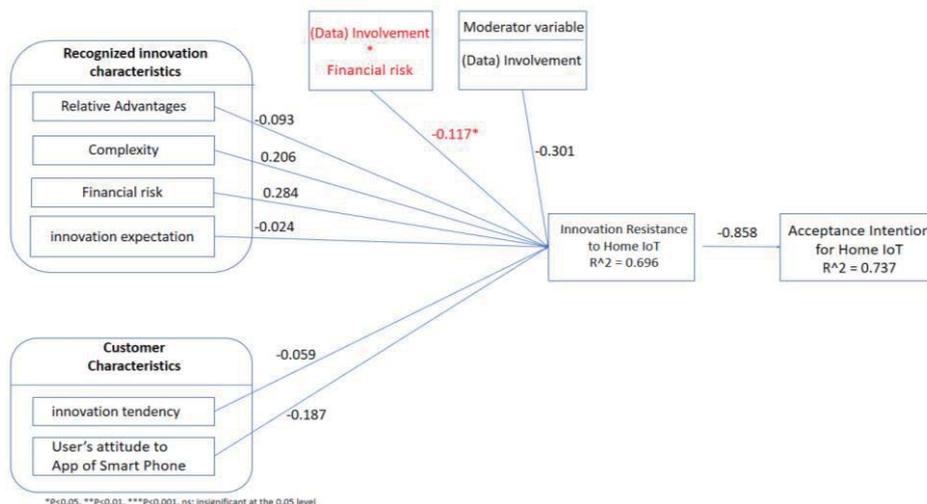
[Table 10. (Data) moderator effect analysis results of involvement]

Categories	Relative Advantages	Complexity	Financial risk	Improved innovation expectations
main effect model	0.685	0.685	0.685	0.685
interacting model	0.686	0.689	0.696	0.694
effect size	0.003	0.013	0.036	0.029
path coefficient	-	-	-0.117	-0.098
analysis result			Moderator effect	

(0.02=small, 0.15=medium, 0.35=large)

Based on the above analysis results for user involvement regarding data, financial risk which is among the recognized innovation characteristics, is confirmed to have moderator effect on the influence towards innovation resistance while improved innovation expectations have an moderator effect on the influence towards innovation resistance thereby adopting hypotheses 2-3 and 2-4, while the other hypotheses 2-1 and 2-2 were denied.

As the user involvement regarding data was confirmed to have negative moderator effect on the relationship between the financial risk and innovation resistance as well as improved innovation expectations and innovation resistance, it can be said that when the user involvement regarding data is high, it has the effect of lowering the innovation resistance against consumer's Home IoT. The explanatory power and path coefficients of the interaction model using PLS are shown in [Figure 7].



[Figure 7. Research model analysis results (moderator effect analysis)]

As a result of verification of the hypotheses, 7 hypotheses out of a total of 11 were adopted, and the summary results are shown in [Table 11].

[Table 11] Hypotheses verification results

No	Research hypothesis	Adopt/Not Adopt
H. 1-1	Relative advantages as one of consumers' innovation characteristics will affect innovation resistance negatively.	Adopt
H. 1-2	Complexity as one of consumers' innovation characteristics will affect innovation resistance positively.	Adopt
H. 1-3	Financial risk as one of consumers' innovation characteristics will affect innovation resistance positively.	Adopt
H. 1-4	innovation expectation as one of consumers' innovation characteristics will affect innovation resistance positively	Not Adopt
H. 1-5	innovation preference as one of consumers' characteristics will affect innovation resistance negatively	Not Adopt
H. 1-6	Existing smartphone app as one of consumers' characteristics will affect innovation resistance negatively	Adopt
H. 1-7	innovation resistance of home IoT services mediating characteristics of innovation & consumers will affect acceptance intention negatively	Adopt
H. 2-1	The influence of relative advantages on innovation resistance will change according to the involvement of the collected data from home IoT devices	Not Adopt
H. 2-2	The influence of complexity on innovation resistance will change according to the involvement of the collected data from home IoT devices	Not Adopt
H. 2-3	The influence of financial risk on innovation resistance will change according to the involvement of the collected data from home IoT devices	Adopt
H. 2-4	the influence of improved innovation expectation on innovation resistance will change according to the involvement of the collected data from home IoT devices	Adopt

## VI. Conclusion

### 1. Study results discussion and implications

This study observed the factors that influence Home IoT innovation resistance based on the innovation resistance model to find the following implications.

First, of the recognized innovation characteristics, relative advantages (-), complexity and financial risk (+) did have influence on innovation resistance of Home IoT service.

Second, of the consumer characteristics, current smartphone app attitude had a negative effect on innovation resistance.

Third, for the user involvement regarding data, financial risk which is among the recognized innovation characteristics, is confirmed to have moderator effect on the influence towards innovation resistance while improved innovation expectations have a moderator effect on the influence towards innovation resistance.

### 2. Theoretical and Practical significance

#### 2.1 Theoretical significance

First, factors that influence innovation resistance of Home IoT service were confirmed via empirical research. Precedent Home IoT studies mostly involve adoption factors of innovation technology and consumer characteristics. This study conducts its studies based on the innovation resistance model to minimize the consumer's natural response which is innovation resistance thereby studying influential factors that are necessary for continued modifications (type of cycle).

Second, consumer innovation acceptance process was understood through the elaboration likelihood model and involvement, and was attempted to explain the current market situation.

Third, deduced variables that reflected the differentiated characteristics of Home IoT, and conducted empirical research to confirm the moderator effect of the user involvement regarding data that influences the recognized innovation characteristics and Home IoT innovation resistance.

#### 2.2 Practical significance

First, as influential factors were confirmed to minimize Home IoT innovation resistance, this can be used in establishing strategies and improving functions for continued improvement with service proliferation.

Second, it has a significance that a company can provide insights in selecting a Home IoT device necessary for a user beyond the scope of simple supplying and selling a terminal equipped with a function. Since complexity and cost can be significantly increased in the process of connecting many devices that are mainly supplier-oriented, companies need to select Home IoT devices that provide the necessary data to consumers and lower the consumer's resistance to innovation.

### 3. Limitations of the study and road ahead

First, since the study was conducted based on certain devices, this study may not have been able to reflect all types of influential

factors that may exist in various Home IoT devices.

Second, of the survey respondents, those with Home IoT service experience mostly had experience with only a specific company's service.

Third, new types of Home IoT services (AI based voice recognition service) was excluded from the study while this study mostly focuses on the Home IoT services that the MNOs generally provide.

Forth, Home IoT is an applied service that creates value via data connection, In this study, however, due to the fact that it mostly focused on the importance of data, it does not deal with value creation based on connection such as autonomous service.

It is suggested that if these limitations would be taken into consideration for future studies and therefore the research would be conducted in various perspectives, then studies will be more significant in contributing to the proliferation of Home IoT service.

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# Cultural Ambidexterity is SME's Secret Weapon for Innovation Success?: The Effect of Strategic Orientation on Innovation Performance

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## ABSTRACT

Innovation is crucial to sustainable growth of small and medium-sized enterprises (SMEs). We aim to explore the effects of a firm's strategic orientations on innovation performance. Specifically, we investigate the possibility of conflicting effects of market orientation (MO) and entrepreneurial orientation (EO) in the context of the Korean technology-based SMEs (i.e. INNOBIZ certified manufacturers). And we analyze an impact of MO and EO on four different types of innovation to explain the better way to manage both MO and EO from perspective of SMEs pursuing technical innovation. We address a simple question: Is there a cultural conflict between MO and EO, and how does it affect SMEs' innovation performance (measured in cost, quality, flexibility, and ROI improvement)? To answer our research question, we collected data from 124 INNOBIZ manufacturers that are certified as innovative small and medium sized enterprises by the Korean Small Business Administration. Moderated hierarchical regression analysis and logistics regression analysis are employed. Academic and managerial implications are presented and future research directions are also discussed.

## KEYWORDS

Entrepreneurial orientation, market orientation, innovation, small and medium sized enterprises

## INTRODUCTION

Innovation is the one of the most important factor to gain sustainable competitive advantages for small and medium-sized enterprises (hereafter SMEs) (Swink, 1999; McDermott, 1999; Fliess & Becker, 2006; Koufteros et al., 2007). Most SMEs are facing serious situations because of increasing global competition, faster technology changes, shortened product life cycles (Humphreys et al., 2005; Singh et al., 2008). For survival, most SMEs are trying to make a breakthrough by developing innovative products, processes, and technologies (Avlonitis & Salavou, 2007; Rhee et al., 2010; Zhang & Duan, 2010; Cakar & Erturk, 2010).

Moreover, many countries have been trying to encourage highly innovative manufacturing SMEs to attain sustainable innovation performance (OECD Oslo Manual, 2005). For example, Korean government made 'INNOBIZ certification program' and gave financial aids and training programs for R&D capability improvements to INNOBIZ certified firms. And in the same vein, U.S. government developed 'Small Business Innovation Research Program' and UK government established 'Business Link' and 'Science Park' programs to foster technical innovation of SMEs. These government supports were attributed to the fact that SMEs play an important role in the national economic growth.

Based on growing interests in technical innovation of small and medium sized manufacturing firm, previous studies focusing on innovation have been suggested various factors driving successful innovation such as R&D intensity (Cohen & Levinthal, 1990; Eberhart et al., 2004; McCutchen & Swamidass, 1996), learning capability or knowledge management (Cohen & Levinthal, 1990; Alegre & Chiva, 2008; Calantone et al., 2002), collaboration networks or external linkage (Okamuro, 2007; Kim & Lui, 2015; Carpenter & Westphal, 2001), commercialization skills (Nevens, 1975), and climate or strategic orientation for innovation (Zhou et al., 2005; Baker & Sinkula, 2009; Covin & Miles, 1999; Renko et al., 2009; Morgan et al., 2015; Atuahene-Gima & Ko, 2001).

In this study, we want to focus the SMEs' strategic orientation as a driving factor of technological innovation performance improvement for two reasons. Firstly, strategic orientation can be viewed as "firm's important capability" (Zhou et al., 2005) or "social learning and selection mechanisms" (Atuahene-Gima & Ko, 2001), and it affects the firm's way to implement their innovation strategy. Because it is a sort of values or philosophies of the firm, and deeply embedded and pervasive cultures, it affects firm's actions in terms of resource allocation, rewards or control system creation, identification of desirable roles of employees, innovation supporting environment creation (Atuahene-Gima & Ko, 2001; Zhou et al., 2005; Li et al., 2006; Morgan et al., 2015). Second, compared with large firm, SMEs tends to more easily be influenced by organizational atmosphere or orientation on innovation when they make decision or take strategic actions. Because most SMEs have insufficient resources to implement their innovation strategy, they should find and focus on specific strategy considered as the most beneficial one for themselves. And when it comes to

organizational structure, SMEs have simple and less bureaucratic structure and small number of employees. It makes them to plant and spread strategic orientation in organization-wide more easily, which in turn be behavioral advantages compared with large firm (Kajalo & Lindblom, 2015; Salavou & Lioukas, 2003; Li et al., 2008; Baker & Sinkula, 2009).

Market orientation (hereafter MO) and entrepreneurial orientation (hereafter EO) have been highlighted in the past literature about innovation as representative two dimensions of the firm's strategic orientation that lead to competitive market positions and successful new products (Morgan et al., 2015).

MO is an organizational culture that may engender product and process innovation activities, focusing on the articulated needs of current customers and information about competitors, and internal coordination for better use of market information. MO consists of three underlying dimensions; customer orientation, competitor orientation, internal coordination. Thus, MO leads to the exploitation of innovation opportunities in the current business domain of the firm. Based on thorough understanding of current market information and interactions with lead-user allow firm can find potential market needs (Zhou et al., 2005).

EO represents a firm's proactive, innovative and risk-taking propensity. It entails exploratory, risk-seeking behaviors that address untapped needs of the current or emerging market. In this study, we focus three key dimensions of EO which is the most-talked about in the past literatures: innovativeness, proactiveness, risk-taking (Covin & Slevin, 1989).

Based on these characteristics of MO and EO, vast researches have investigated how these two strategic orientations affect innovation or business performance. MO has long been in the spotlight in marketing journal as an antecedent of new product development and overall business performance improvement. Because MO makes firm assess current existing customer needs or competitor's actions thoroughly, the risks of failure of innovative actions are minimized, and they can extend their brand or line stably (Frishammar & Horte, 2007). Also firm with strong MO can improve their quality of innovation because they tune their innovation strategy according to market changes. 'Customers' insight' and 'lead user technique' make firm develop even unarticulated needs and in turn increase the introduction of new-to-the-world products (Slater & Narver, 1998).

Meanwhile, EO was broadly researched by management field. Past researches stressed that firm with strong EO tends to reinforce investments in their innovation strategy implementation, and doesn't worry about the risks of failure. This firm may put bigger emphasis on a development of products or technologies that has not even been conceptualized yet. So they can create or pre-empt customers' unexpressed needs, and take first mover advantages (Baker & Sinkula, 2009; Zhou et al., 2005)

Some prior research suggests that MO and EO are important strategic orientations and organizational cultures driving innovation, and either of one alone is not sufficient for sustainable competitive edge (Baker & Sinkula, 2009; Atuahene-Gima & Ko, 2001; Li et al., 2008). Researchers explained the reason why firm need both two different kinds of strategic orientation in various ways. Most studies highlighted an additive or interactive relationship between MO and EO. Slater and Narver (1995) argued that MO and EO should be complemented to generate "appropriate organizational structures and processes for higher-order learning" because each MO and EO facilitates different organizational learning culture. They said firm who has both MO and EO can minimize the risk and maximize frame breaking actions based on generative learning.

Some researchers investigated relationship between MO and EO in different ways. Matsuno et al. (2002) and Raju et al. (2011) suggested that EO facilitates organization members' willingness and ability to undertake learning activities based on current market information, and eventually promotes MO. Bhuian et al. (2005) indicated that the synergistic effect of MO and EO on business performance follows an inverted U shape, which means that the positive effect of MO on business performance become greater at a moderate level of EO.

Many studies investigated positive relationship between each strategic orientation and innovation performance (Renko et al., 2009; Li et al., 2006; Zhou et al., 2005). Yet, it is hard to conclude that MO and EO are mutually complementary, still remains to be empirically tested, since prior research has reported mixed results (Atuahene-Gima & Ko, 2001; Nasution et al., 2011; Gonzalez-Benito et al., 2009; Merlo & Auh, 2009). Atuahene-Gima & Ko (2001) classified MO and EO into four groups, which are market and entrepreneurship oriented (ME), entrepreneurship oriented (EO), market-oriented (MO), and conservative (CO) firms. And they investigated empirically how these groups of firms differ with regard to innovation performance measures, such as new product performance, timing to market entry, product quality, and market synergy and so on. They found that each groups have an impact on innovation performances with different intensity, firm who has both high level of MO and EO hold dominant position in most case of innovation performance, but not in timing to market entry and market synergy. Renko et al. (2009) hypothesized positive impacts

of MO, EO, and technological capability on product newness, but there are not empirically significant relationships among them. Baker and Sinkula (2009) suggested that MO has positive impact on profitability but not on innovation success, while EO has non-significant effect on profitability but on innovation success, and these are empirically supported.

And we found that there is the paucity of studies focusing on strategic orientation of SMEs and their innovation performance, while SMEs can shape and be influenced their organizational culture more easily than bigger firms (Singh et al., 2008; Humphreys et al., 2005; Nguyen & Mohamed, 2011). Especially, no research has yet examined conflicting effect of MO and EO when SMEs pursue it simultaneously. Because SMEs be characterized by lack of resources and lack of experiences in innovation management, it is essential to check the differences compared with large-sized firms when SMEs utilize two different culture or orientation toward innovation at the same time.

To address the limitations of prior studies, we investigate the possibility of conflicting effects of MO and EO in the context of the Korean technology-based SMEs (i.e. INNOBIZ certified manufacturers). We want to explain the better way to manage both MO and EO for innovation performance improvement from perspective of SMEs pursuing technical innovation. We address a simple question: Is there a cultural conflict between MO and EO, and how does it affect SMEs' innovation performance (measured in cost, quality, flexibility, and ROI improvement)?

To answer our research question, we collect data from 124 technology-oriented small manufacturing firms in Korea. Result shows that SMEs can be suffered from cultural conflict when they pursue both MO and EO simultaneously. Post-hoc analysis result explains the reason of this cultural conflict more concretely. Finding indicates that each MO and EO leads different kinds of technical innovation. MO affects positively incremental product innovation, while EO drives radical process and product innovation. It can be interpreted that each MO and EO encourages different organizational learning culture, and requires different kinds of resources to implement their innovation strategy.

In the following section, we develop hypothesis that negatively link the interaction of MO and EO to innovation performance based on literature review. We then describe our sampling and data collection process. Finally, we discuss our findings of this study and explain our theoretical and managerial implications or insights generated by empirical results.

## **THEORETIC BACKGROUND AND HYPOTHESIS DEVELOPMENT**

Narver and Slater (1990), one of the most representative studies which conceptualized MO, define MO as “the organizational culture that most effectively creates the necessary behaviors for the creation of superior value for buyers and thus continuous superior performance for the business”. They delineate MO into three behavioral dimensions: customer orientation, competitor orientation, and inter-functional coordination.

Some researchers argued that too listening carefully current customers' voices is harmful to product newness or radical innovation. They contended that customer orientation is just a source of marginal innovation because of the imperfection of customer information, customer's limited domains of experience, tyranny of the serving market, current customer's inertia and so on. And competitor orientation might just lead to product imitation because firm can conveniently copy ideas or technologies of competitors (Grinstein, 2008; Lukas & Ferrell, 2000; Abdullah & Aimin, 2015).

This debate continues, however, most studies agree that highly innovative SMEs can gain more innovation performance when they have strong customer and competitor orientation. Customer orientation help SMEs reduce technological innovation-related risks effectively. Accurate and appropriate information about current market or customer make them assess more precisely which one is the most promising project or product. And this intelligence trigger investment for new research or patent projects in early stage of technological innovation and motivate them to more focus on R&D activities for highly promising projects with certainty (De Luca et al., 2010). Especially, most SMEs are lack of resources or capabilities to conduct innovation strategy sufficiently because they may have fewer capital and employees, undeveloped education or training programs, narrow market niche, and weak external contacts (Bigliardi, 2013). In this situation, accurate and up-to-date market intelligence is crucial for their technological innovation success.

And competitor oriented SMEs can indirectly learn from their rivals' trial and error, which in turn help them reduce number of and cost of failure or error (De Luca et al., 2010). Most SMEs are suffering from limited or insufficient resources – capital, level of technical expertise, number of employees, external network for NPD, etc. - to fully implement their innovation strategy. It means that they need to find the most competitive point of their new products or services and focus on specific processes or products as a NPD project, not invest money in various innovation projects. In that respect, competitor orientation help SMEs catch ‘industry recipes’ or ‘industry trends’ and increase efficacy and

effectiveness in the R&D process by tuning their R&D strategy based on knowledge learned from other firms' cases (Im & Workman, 2004; De Luca et al., 2010).

Inter-functional coordination can be described as a climate to facilitate cooperation or collaboration to share market oriented culture or market intelligence, goals or visions of technological innovation among functional subunit of the firm (Lukas & Ferrell, 2000; De Luca et al., 2010; Im & Workman, 2004; Grinstein, 2008). It reduces current or potential conflict among members of functional subunits by eliminate knowledge sharing delays or imperfect decision making (De Luca et al., 2010; Henard & Szymanski, 2001).

In conclusion, market orientation allow firms more easily assess, respond to, and listen to their existing customer's needs whether it is expressed or latent, which in turn help to be first to market with new generations of existing products or services. Firm with strong MO tends to focus on 'brand or line extension and tuning' (Frishmmar & Horte, 2007), it is helpful to attain sustainable profit and stable operations, and increase efficacy and effectiveness of R&D process with the minimal investments (Baker & Sinkula, 2009). MO allow firms achieve commercialization success even in high demand uncertainty because they always pay close attention to current customers' taste (Slater & Narver, 1998).

EO had been conceptualized as an organizational culture that "engages in product marketing innovation, undertakes somewhat risky ventures, and is first to come up with proactive innovation" (Miller, 1983), and operationalized into three dimensions: innovativeness, risk-taking, proactiveness (Miller, 1983; Morris & Paul, 1987; Covin & Slevin, 1989).

Although few studies warned that over-emphasizing on EO is too risky for firm and may lead to launch premature product or process which in turn make customers feel extreme unfamiliarity and thus forgo purchases (Atuahene-Gima & Ko, 2001), most researchers argue that EO is the most powerful culture to encourage and lead innovation in organization-wide (Frishammar & Horte, 2007; Covin & Miles, 1999; Zhou et al., 2005; Baker & Sinkula, 2009).

EO is technology-driven internal culture that encourages members to actively develop innovative ideas and products (Lumpkin and Dess, 1996; Zhou et al., 2005; Morgan et al., 2015). Also it allows substantial financial or managerial commitment in the organization-wide (Zhou et al., 2005; Li et al., 2006).

Innovativeness allow firm to seek "meaningful uniqueness" in product or process innovation as a culture or climate that encourage continuous exploration or experimentation of new ideas (Frishammar & Horte, 2007). Risk-taking is a tendency to invest heavily in projects or technologies where the possibility of failure may be high, or willingness to commit large amounts of resources without the fear of failure (Li et al., 2008; Renko et al., 2009; Lumpkin & Dess, 1996). Proactiveness focuses on forward-looking, taking first-mover advantages by environment shaping or seizing new opportunities (Lumpkin & Dess, 1996; Zhou et al., 2005). It is helpful to gain high profits from new technologies or products in condition where competitors doesn't exist, and develop new things more speedily (Frishammar & Horte, 2007; Renko et al., 2009).

Focusing on customers' unexpressed or unarticulated needs without concern of failure make firm pre-empt customer needs (Morgan et al., 2015) and create products ahead of customer actual needs or competitors, which in turn make firm takes first mover advantage (Baker & Sinkula, 2009). Firm with strong EO may try to make the new-to-the-world products and create customer needs. EO makes firms set their new product or process as industry standards, and can make a price first and sell at a high price (Merlo & Auh, 2009; Zhou et al., 2005; Baker & Sinkula, 2009; Li et al., 2006).

Based on these characteristics of each MO and EO, numerous studies suggested that firms can fully benefit when they have both MO and EO. Since each MO and EO has different role in the establishment or implementation of innovation strategies, they pointed out possessing both MO and EO create synergistic effect by making up for the weakness and at the same time maximizing the advantages (i.e. interactive perspective) or accumulate merits of each MO and EO as the sum of their individual effects per se (i.e. additive perspective). MO is useful for acquiring, absorbing, exploiting the market information whereas EO is effective in proactive investment in R&D activities and exploration. Frishammar and Horte (2002) argued that MO and EO can coexist because they are 'two separate, but complementary strategic orientations', and these two orientations generate 'complex, tacit, and intangible skills' that encourage new idea generation. Reduce development cost, and increase production flexibility by removing obstacles (Li et al., 2006)

More specifically, MO allow firm to reduce risks from new product development through an assessment and exploitation of current market intelligence while EO speed up development process with sufficient investments (Atuahene-Gima & Ko, 2001; Li et al., 2008; Nasution et al., 2011; Menguc & Auh, 2006; Gonzalez-Benito et al., 2009). Therefore firms can produce unique products tailored to market needs (Atuahene-Gima & Ko, 2001; Morgan et al., 2015), pioneer the technological and market advantage (Atuahene-Gima & Ko, 2001), reduce development cost, and increase production

flexibility by removing obstacles (Li et al., 2006)

From interactive perspective, previous researches presented a variety of views of the point that synergistic effect appears. And they also stressed the importance of 'balance' between MO and EO which means that both MO and EO keep the highest level or similar level which is not over emphasizing in any particular orientation (Autuahene-Gima & Ko, 2001; Bhuian et al., 2005; Matsune et al., 2002). However, the empirical results of these studies are mixed and increase our confusion as to how to manage both MO and EO at the same time. Nasution et al. (2011) hypothesized a positive interaction effect between MO and EO on innovation, but it is not supported. Gonzalez-Benito et al. (2009) suggested that the interaction of MO and EO has a positive impact on new product success, but it was found to be not significant in new product success. Atuahene-Gima and Ko (2001) found that firms who have both MO and EO at the highest level couldn't perform better than MO focused firms or EO focused firms in terms of timing to market entry and market synergy. Further, Morgan et al (2015) indicated that MO acts negative moderator on the positive relationship between EO and new product development performance (e.g. market share, sales growth, sales and customer use, profit) using 206 Swedish mid-sized manufacturing firms.

It is hard to find a clear answer whether complementary effect would happen, and whether having both MO and EO is always good for SMEs' technical innovation or not. Moreover, there is a lack of empirical research on the interaction effect of MO and EO on technical innovation performance improvement from the SMEs side. Considering the fact that SMEs are more strongly influenced by their organizational culture in the event of the establishment and implementation of organizational strategy compared with large firm (Bigliardi, 2013; Nguyen & Mohamed, 2011), it is necessary to study the interaction of MO and EO in terms of SMEs' technical innovation.

SMEs are described as firms that have less bureaucratic organizational form, relatively simple organizational structure and systems. These characteristics allow SMEs maintain 'flexible cultures for the innovation'. That is to say, SMEs may have relatively short decision-making process, share external information more easily and quickly across the firm, and respond to customer needs more quickly and flexibly than large firms (Singh et al., 2008). Having "relatively low resistance to change, low risk aversion, and tolerance of ambiguity than larger firm" are another peculiarities of SMEs (Terziowski, 2010).

SMEs also be represented by 'lack of resources and capabilities, small number of employees, lack of external network as a source of valuable information, narrow market niche, and insufficient organizational learning and training programs (Bigliardi, 2013; Terziowski, 2010). In essence, there is a strong possibility that SMEs be more suffered from constraints of resources, technologies, and capabilities than large firms. And because it would be difficult for SMEs to achieve the economy of scale or the economy of scope on account of their firm size, SMEs cannot help spending lots of money to develop and maintain new product or process. Due to these characteristics, SMEs tend to focus on short-sighted innovation strategies or allocate resources to avoid the next crisis. And SMEs can't afford to implement multiple strategies or gain multiple technological competencies at the same time owing to resources and capabilities constraints. Further, SMEs have difficulties in conducting business or organizational learning systematically, and seizing external opportunities for innovation in general.

Therefore, past studies considered culture or climate of SMEs as one of the important capabilities which help SMEs exploit their resources and explore new opportunities while overcome their fundamental imperfection. Nguyen and Mohamed (2011) suggested that SMEs' organizational culture can be a capability for integrating all activities in the organization from top management level to shop floor employee level to meet the planned goals. Organizational culture allows firm rapidly modify their process or allocate resource to reflect environmental changes because this organizational culture makes the directions for priority setting, guides members in their roles and duties in the organization, and encourages SMEs to share organizational value or norms about innovation.

Especially the decision-making process in SMEs is prone to "be centralized at the owner or top management level" (Nguyen & Mohamed, 2011, p.210). And most SMEs are likely to "be entirely enveloped in a culture" (Humphreys et al., 2005, p.285). Having right innovation cultures which are fit with organizational systems and strategies is most crucial factor for SMEs to attain sustainable innovation performance improvement.

To sum it up, SMEs tend to be influenced by a single dominant culture (Nguyen & Mohamed, 2011; Humphreys et al., 2005) and not suitable for having or utilizing multiple culture at the same time. Therefore, the priorities in decision-making, specific action for innovation, and types or amount of investment can be varied depending on what kinds of cultures or orientations toward innovation SMEs has, which values SMEs want to pursue. Also it is possible to take place different kind of innovations or gain different level of performance depending on the innovation culture or strategic orientation they have.

Fundamentally, MO and EO are represented by two completely different kind of strategic orientation or organizational culture. So SMEs may feel burdened by simultaneous pursuit of both MO and EO due to their resources and capabilities constraints or an occurrence of cultural crash. For example, SMEs may face conflicts or difficulties because each business unit might have different priorities for the decision-making process or resource allocation to implement innovation strategy specifically. And the disadvantages from informality would be maximized due to the chaos as to which they should take on first or where they should invest more. For these reasons, cultural conflict can happen, and which in turn be disadvantageous to innovation success of SMEs.

Earlier studies showed that firms with strong MO regard exploiting market information obtained from current customer and competitor as the most important sources of competitive advantages. They may decide carefully where they invest their resources in based on thorough market information analysis, and make products which perfectly suit current customers' taste. And they tend to focus on 'brand or line extension and tuning' (Frishmmar & Horte, 2007), it is helpful to attain sustainable profit and stable operations, and increase efficacy and effectiveness of R&D process with the minimal investments (Baker & Sinkula, 2009). On the other hand, firms with strong EO think that pre-empting new market or creating new technology is the key to survive, and take heavy investment in generative and exploratory learning for granted to develop technology and product which hasn't even been conceptualized yet. Although EO makes firms set their new product or process as industry standards, and can make a price first and sell at a high price (Merlo & Auh, 2009; Zhou et al., 2005; Baker & Sinkula, 2009; Li et al., 2006), firms might be hard to get commercialization success in a short time. That is to say, market-oriented culture make firm be more likely to pursue exploitative activities whereas entrepreneurial-oriented culture make firm be inclined to conduct more exploratory activities for innovation. Each MO and EO affects positively innovation performance improvement, though each emphasizes different kinds of activities.

However, SMEs who quest for MO and EO at the same time tend to seldom improve their innovation performance than market-oriented or entrepreneurial-oriented SMEs.

***Hypothesis 1.** Simultaneous pursuit of MO and EO has negative effect on (attenuates) SMEs' innovation performance improvement.*

## **SAMPLE AND DATA COLLECTION**

To test the proposed hypotheses, we collected data from technology-oriented small manufacturing firms in Korea. Specifically, we targeted INNOBIZ certified manufacturers as our research sample. INNOBIZ is a combination of the words innovation and business. INNOBIZ certification program started from February 2001 based on Small and Medium-sized Enterprises Technology Innovation Promotion Act No.15 in Development and Cultivation of Innovation Business Law. INNOBIZ firms are 'technology intensive and innovation oriented SMEs', and selected by Korean government on the basis of the evaluation about each firm's innovativeness(Rhee et al., 2010). The evaluation indices are based on OSLO manual of OECE, and are composed of four key dimensions; technical innovation capability, technical commercialization capability, technical innovation management capability, technical innovation performance. INNOBIZ certified firms benefit from Korean government such as financial aids, training programs for R&D capability improvements, and they are granted privileges for entering a new market and so on. Considering INNOBIZ certified small and medium-sized manufacturing firms as our target responding firms is appropriate to investigate the effect of strategic orientation on innovation performance improvement.

In 2010, INNOBIZ certified firms are about 16000 in total. We excluded firms who do not want to open their information, 4840 INNOBIZ certified manufacturing firms of the rest are our study's population. We randomly selected 1275 firms from 4840 INNOBIZ certified manufacturing SMEs. The unit of analysis of this study is a business unit, and we conducted survey with single respondent of each firm. Our target respondent is business unit heads, chief R&D officers, or senior development managers who were most likely to understand R&D strategies and activities of their firm. We asked them to answer the questions about their organization-wide strategic orientation and technical innovation performance in the past three years (from 2007 to 2009). The survey instrument was reviewed by two operations management professors, and then questionnaire was pretested with MBA students, and revised for readability and validity. All selected firms were contacted via phone and asked for participation, and 529 firms agreed to participate in the study. On-line and off-line surveys were collected and finally collected 124 responses in total (response rate= 9.73%). The respondents have been working for their company for 6.7 years on average. Approximately 76.6% of respondents

are working in the R&D department, and 14.5% of respondents are being employed in the business management department. Table 1 reports sample distributions by industry, the number of employees, and R&D intensity.

**TABLE 1**

*Sample Distribution: Industry, Number of Employees, and Sales*

	Frequency	Percent
<b>Industry</b>		
Chemicals & Plastics	20	16.2
Construction	5	4.0
Electronics	28	22.6
Metal & Machine	34	27.4
Pharmaceutical	7	5.6
Transportation	7	5.6
Others	2	18.5
<i>Total</i>	<i>124</i>	<i>100</i>
<b>R&amp;D intensity</b>		
<2	18	14.5
2-3.99	36	29.0
4-5.99	30	24.2
6-7.99	3	2.4
8-9.99	3	2.4
10-19.99	17	13.7
Over 20	17	13.7
<i>Total</i>	<i>124</i>	<i>100</i>
<b>Number of employees</b>		
≤50	44	35.5
51-100	42	33.9
101-150	20	16.1
151-200	8	6.4
201-250	8	6.4
251-300	2	1.6
<i>Total</i>	<i>124</i>	<i>100</i>
<b>Firm sales (Million USD)</b>		
≤1000	11	8.87
1001-3000	8	6.45
3001-5000	8	6.45
5001-10000	34	27.42
10001-50000	54	43.55
Over 50001	9	7.26
<i>Total</i>	<i>124</i>	<i>100</i>

## MEASURES

We use seven-point Likert scale to assess respondents' answers on all multi-item constructs. MO was measured based on three different sets of questions pertaining to customer orientation, competitor orientation, and inter-functional coordination (see Table 2). The scale was adapted from Zhou et al. (2005), who borrowed it from Narver & Slevin (1990).

We adapted EO scale from the work of Covin and Slevin (1989). EO also consists of three different sets of questions including innovativeness, proactiveness, and risk-taking (see Table 2). Our dependent variable is formative, and indicates the extent of SMEs' innovation performance improvement in terms of return of investment (ROI), product quality performance, cost reduction, production flexibility. This scale is based on the work of (Zhou et al., 2005).

We used further dependent variables in the post hoc analysis. We asked firms whether they conduct each four different

types of innovation or not. Each four different types of innovation variables are binary variables that take the value '0' or '1'. For instance, if firm achieves incremental process innovation in the past three years, it is coded as a '1' and a '0' otherwise. Our classification of types of technical innovation is grounded on the works of Dewar and Dutton (1986), Damanpour (1991), OECD Oslo Manual (2005).

We incorporated several control variables to account for extraneous effects. First, we included industry dummy variables to control the effect of industrial differences. Metal and machinery industry is set as the base industry and the effects of other industries are measured as deviations from the base (Carey et al., 2011). Second, we control for firm size which may affect SMEs' innovation performance, because relatively larger firms possess greater and more heterogeneous resources to improve their innovation performance compared with firm who doesn't have enough resources or capabilities (Yli-Renko, 2001). We measure firm size as the natural logarithm of the number of employees in 2010 (Yli-Renko et al., 2001). Third, older firms are regarded to have wide and deep knowledge in innovation, various technologies, abundant innovation experiences which have accumulated for a long time. And these affect firm's innovation performance (Yli-Renko et al., 2001; Zaheer & Bell, 2005). We measure firm age as the number of years elapsed since the founding of the firm. Lastly, we added R&D personnel ratio and R&D intensity to control the differences in the amount of innovation resources (Eberhart et al., 2004). Following prior studies, R&D personnel ratio is measured with the ratio of the number of R&D employees to the number of total employees. And R&D intensity is calculated from the percentage of the total expenses related to R&D (self-development, co-development, entrusted development, technology introduction) in total sales in the past 3 years.

### **Measurement Assessment**

To determine reliability and validity of our measurement, we conducted several analyses. First, a result of exploratory factor analysis to assess unidimensionality suggested to us that all measurement variables loaded the intended latent constructs (Koufteros et al., 2007). Further, we assessed reliability through Cronbach's alpha and composite reliability, each estimate of measurement variables is more than 0.7 which is recommended value in many researches (Hair et al., 2010). Table 2 describes the result explained above.

We conducted confirmative factor analysis to check construct validity, and overall fit of our measurement was acceptable (normed  $\chi^2=1.450$ , comparative fit index = 0.948, incremental fit index = 0.949, root mean square error of approximation = 0.061). Convergent validity is established if each indicator's estimated loading on its assumed underlying construct is significant (Anderson & Gerbing, 1988). We can verify convergent validity of our measurement items if standardized loading estimates and average variance extracted (AVE) be equal to 0.5 or higher (Hair et al., 2010). As Table 2 demonstrates, all measurement items loaded significantly on their intended constructs, and their loadings were greater than 0.5. In addition, all AVEs demonstrated on the diagonal in Table 3 were greater than 0.5, thus it provides evidence of convergent validity. For discriminant validity, we checked whether the AVE of each construct is greater than square of the correlation estimates shown in the off-diagonals of Table 3 (Fornell & Larcker, 1981). We found that none of average shared variances is greater than their corresponding AVEs, thus confirming the discriminant validity of all latent constructs.

### **Non Response and Common Method Bias**

To determine nonresponse bias, we compared total sales amount in 2010 and the number of employee of 124 respondent firms with those of 124 non-respondent firms, and found no statistically significant difference between the two groups. And we conducted Harman's one-factor test to check common method variance (hereafter CMV) (Podsakoff et al., 2003). As a result, an un-rotated factor analysis of all dependent and independent variables revealed that a total of 71.6% of variance was accounted for, and that the first factor captured only 43.8% of the variance, ensuring that CMV was not a significant problem in this study.

**TABLE 2**  
*Constructs and Indicators*

Construct	Measurement variables	Mean	SD	Loadin <sup>a</sup> g	t-value	Cronbach a	Composite Reliability
<i>Please indicate the degree to which you agree to the following statements concerning your company's strategic orientation (1=strongly disagree, 7= strongly agree):</i>							
<b>Market Orientation</b> (Narver & Sletten, 1990; Zhou et al., 2005)	Customer Orientation	MO1	We have a high level of customer commitment	5.08	1.25	0.529	-
		MO2	Creating customer value is the core to our business strategy	5.11	1.11	0.632	6.871
		MO3	Understanding customer needs is the bedrock of competitive advantage	5.30	1.18	0.631	5.297
		MO4	Customer satisfaction is the primary objectives of our business	5.45	1.21	0.703	5.63
		MO5	We frequently measure customer satisfaction	4.52	1.31	0.681	5.539
		MO6	We put emphasis on after-sales service	4.77	1.44	0.674	5.515
	Competitor Orientation	MO7	Salespeople share competitor information	4.66	1.32	0.527	4.716
		MO8	We respond rapidly to competitors' actions	4.99	1.19	0.703	5.652
		MO9	Top managers discuss competitors' strategies	5.18	1.30	0.727	5.734
		MO10	We focus on target opportunities for competitor advantage	5.36	1.14	0.795	6.025
							.930
	Interfunctional Coordination	MO11	Interfunctional team members communicate our customer	4.42	1.28	0.712	5.664
		MO12	Information is shared among functions	4.88	1.23	0.732	5.777
		MO13	Functional strategies are integrated	4.64	1.23	0.742	5.821
		MO14	All functions contribute to customer value	4.86	1.32	0.764	5.91
MO15		We share resources with other business units	4.91	1.27	0.658	5.439	
<i>Please indicate the degree to which you agree to the following statements concerning your company's strategic orientation (1=strongly disagree, 7= strongly agree):</i>							
<b>Entrepreneurial Orientation</b> (Covin & Slevin, 1989)	Innovativeness	EO1	Very many new lines of our products or services were marketed in the past 3 years	4.65	1.34	0.655	-
		EO2	Changes in our product or service lines have usually been quite dramatic	4.56	1.35	0.614	10.884
	Proactiveness	EO3	In dealing with its competitors, my firm typically initiates actions which competitors then respond to	4.53	1.11	0.8	7.415
		EO4	In dealing with its competitors, my firm is very often the first business to introduce new products/services, administrative techniques, operating technologies, etc.	4.56	1.18	0.795	7.377
		EO5	In dealing with its competitors, my firm typically adopts a very competitive, 'undo-the-competitors' posture	4.61	1.12	0.738	6.966
	Risk-taking	EO6	In general, the top managers of my firm have a strong proclivity for high-risk projects with chances of very high returns	3.98	1.28	0.451	4.514
		EO7	In general, the top managers of my firm believe that owing to the nature of the environment, bold, wide-ranging acts are necessary to achieve the firm's objectives	5.02	1.29	0.445	4.461
		EO8	When confronted with decision-making situations involving uncertainty, my firm typically adopts a bold, aggressive posture in order to maximize the probability of exploiting potential opportunities	4.65	1.33	0.661	6.367
					.867	.937	

<sup>a</sup>Standardized loadings from confirmatory factor analysis., significant at p <0.001

TABLE 2 (CONTINUED)

Constructs and Indicators

Construct	Measurement variables	Mean	SD	Loading <sup>a</sup>	t-value	Cronbach $\alpha$	Composite Reliability
<i>Please evaluate the effect of process and product innovation your firm conducted in the past 3 years(2007-2009)</i>							
<b>Innovation Performance</b> (Zhou et al., 2005)	FP1 ROI increase	4.34	1.19			Formative	
	FP2 Product quality and performance increase	4.95	1.10				
	FP3 Cost reduction	4.55	1.11				
	FP4 Production flexibility improvement	4.40	1.11				
<i>Please select the types of innovation your firm conducted in the past 3 years(2007-2009)</i>							
<b>Types of Innovation</b> (Gatingnon & Xuereb, 1997; Zhou et al., 2005; Stamm, 2003)	FF1 Firm first (not market-first) process innovation (Yes=1, No=0)					Biinary	
	MF1 Market first process innovation (Yes=1, No=0)					Binary	
	FF2 Firm-first (not market-first) product innovation (Yes=1, No=0)					Binary	
	MF2 Market-first product innovation (Yes=1, No=0)					Binary	
<b>Firm age</b> (Yli-Renko et al., 2001; Zaheer & Bell, 2005)	The number of years elapsed since the founding of the firm	17.77	10.19			-	
<b>Firm size</b> (Yli-Renko et al., 2001)	The natural logarithm of the number of employees	4.27	0.68			-	
<b>R&amp;D personnel ratio</b>	The ratio of the number of R&D employees to the number of total employees	13.14	12.76			-	
<b>R&amp;D intensity</b> (Eberhart et al., 2004)	The percentage of the total expenses related to R&D(self-development, co-development, entrusted development, technology introduction) in total sales in the past 3 years	8.43	12.30			-	
<b>Industry</b> (Carey et al., 2011)	Base= Metal and Machinery, Chemical, Construction, Electronic, Pharmaceutical, Transportation, Others					Binary	

<sup>a</sup>Standardized loadings from confirmatory factor analysis., significant at p <0.001

**TABLE 3**

*Means, Standard Deviations, Pearson Correlation Coefficients, and Average Variance Extracted*

	Mean	SD	(1)	(2)	(3)	(4)	(5)	(6)	(7)
1. Market Orientation	4.943	0.889	.621 <sup>a</sup>						
2. Entrepreneurial Orientation	4.572	0.900	.643 <sup>***</sup>	.656 <sup>a</sup>					
3. Innovation Performance	4.569	0.877	.499 <sup>***</sup>	.532 <sup>***</sup>	-				
4. Firm Age	17.774	10.195	-.026	-.134	-.046	-			
5. Firm Size	4.271	0.680	.174 <sup>+</sup>	.051	.088	.166 <sup>+</sup>	-		
6. Number of employee for R&D	13.143	12.763	-.022	.057	.149 <sup>+</sup>	-.103	-.411 <sup>***</sup>	-	
7. R&D Intensity	8.427	12.297	-.053	.001	.111	.075	-.145	.173 <sup>+</sup>	-

<sup>†</sup>  $p < .1$ ; <sup>\*</sup>  $p < .05$ ; <sup>\*\*</sup>  $p < .01$ ; <sup>\*\*\*</sup>  $p < .001$

<sup>a</sup> Average Variance Extracted; AVE

## ANALYSIS AND RESULTS

### Moderated Hierarchical Regression Analysis

We conducted moderated hierarchical regression analysis to test our hypothesis. We followed the procedure suggested by Aiken and West (1991) and Cohen et al. (2003). We mean-centered both MO and EO, and created interaction term by multiplying mean-centered MO and EO. Model 1 includes industry dummies and firm age, firm size, R&D personnel ratio, and R&D intensity as control variables. Mean-centered MO and EO are added to Model 2. And two-way interaction term between MO and EO is inserted in Model 3, testing our hypothesis 1. The result of moderated hierarchical regression analysis is presented in Table 4.

Variance inflation factors (VIF) of all regression coefficients in Model 3 range from 1.11 to 1.92 and are below the recommended critical value of 10 (Cohen et al., 2003), implying that multicollinearity is not a significant concern. The full regression model, as shown in Model 3, explains 40.3% of the observed total variance related to the supplier’s innovation performance improvement, and is statistically significant ( $F=5.718, p<0.001$ ).

The result in model 3 fully supports our hypothesis 1 (unstandardized  $\beta = -0.121, SE=0.064, p=0.064$ ). Hence, the regression coefficient of the interaction term between MO and EO is significantly negative impacts on SMEs’ innovation performance improvement, supporting hypothesis 1.

We conducted further statistical analysis to suggest more in-depth clarifications about cause of negative interaction effect. We aimed to explore what kind of technical innovation can be driven by each MO and EO. We classified small and medium-sized manufacturing firms’ technical innovation into four different types of innovation according to two dimensions. It can be distinguished incremental innovation and radical innovation based on a degree of radicalness, and process innovation and product innovation based on an objective of innovations. Briefly, process innovation can be defined as the introduction or implementation of significant improved production or delivery method for cost, quality issue. Product innovation is the introduction of a good or service that is new or significantly improved regarding its characteristics or intended uses. Radical innovation is “fundamental changes in the activities of an organization and clear departures from existing practices”, and incremental innovation is “a variation and routine and instrumental innovation that result in little departure from existing practices.” (Damanpour, 1991; p.561)

TABLE 4

*Moderated Regression Results for SMEs' Innovation Performance Improvement*

	Dependent Variable = Innovation Performance Improvement					
	Model 1		Model 2		Model 3	
	Estimate	Std err	Estimate	Std err	Estimate	Std err
<b>Industry dummy</b> (base= Metal & Machinery base)						
Electronics	-.034	.224	-.070	.185	-.094	.184
Chemical & Plastics	-.098	.230	.000	.192	-.006	.190
Pharmaceutical	-.107	.328	.212	.276	.191	.273
Transport	.269	.341	.228	.283	.222	.280
Construction	.297	.394	.479	.328	.474	.324
Others	-.310	.313	-.038	.263	-.085	.261
<b>Firm-level Control</b>						
Firm age	-.008	.008	-.002	.007	-.001	.007
Firm size	.268	.132	.156	.111	.143	.110
R&D personnel ratio	.015*	.007	.013*	.006	.013*	.006
R&D intensity	.008	.007	.010 <sup>+</sup>	.006	.010 <sup>+</sup>	.006
<b>Independent variables</b>						
MO			.261**	.100	.225*	.101
EO			.353***	.097	.346***	.096
<b>Interaction</b>						
MO x EO (H1)					-.121 <sup>+</sup>	.064
R <sup>2</sup>	.087		.384		.403	
Adjusted R <sup>2</sup>	.006		.318		.333	
F-value	1.076		5.771		5.781	
R <sup>2</sup> change	.087		.297		.019	
F change	1.076		26.791		3.511	
p-value	.387		.000		.000	

<sup>+</sup>  $p < .1$ ; \*  $p < .05$ ; \*\*  $p < .01$ ; \*\*\*  $p < .001$ , All estimates are unstandardized coefficient

We employed logistic regression to analyze empirically the impact of MO and EO on these four different types of technical innovation. As shown in Table 5, results of logistic regression analysis support that MO leads only incremental product innovation (unstandardized  $\beta=0.761$ ,  $SE=0.332$ ,  $p=0.022$ ). And MO has a negative effect on radical product innovation at the  $\alpha=0.1$  significance level (unstandardized  $\beta=-0.596$ ,  $SE=0.350$ ,  $p=0.089$ ). On the other hand, EO conduces to both radical process innovation (unstandardized  $\beta=0.743$ ,  $SE=0.363$ ,  $p=0.041$ ) and radical product innovation (unstandardized  $\beta=0.930$ ,  $SE=0.351$ ,  $p=0.008$ ).

TABLE 5

*Logistic Regression Results for Types of Innovation*

Dependent Variable	Independent Variable	Estimates	Std. error	Walds Chi-square	p-value	Odds ratio
<b>Incremental Process Innovation</b>	(industry dummy variables are included)					
	Firm age	-.038	.020	3.579	.059	.963
	Firm size	.109	.323	.113	.737	1.115
	R&D intensity	-.007	.017	.159	.690	.993
	R&D personnel ratio	.017	.017	1.006	.316	1.017
	<b>MO</b>	-.070	.292	.058	<b>.810</b>	.932
	<b>EO</b>	.471	.293	2.576	<b>.108</b>	1.602
-2 Log likelihood			158.230			
Cox & Snell R-square			.102			
Nagelkerke R-square			.136			
<b>Incremental</b>	(industry dummy variables are included)					

<b>Product Innovation</b>						
	Firm age	-.024	.022	1.249	.264	.976
	Firm size	.391	.363	1.164	.281	1.479
	R&D intensity	.029	.024	1.440	.230	1.030
	R&D personnel ratio	.016	.019	.699	.403	1.016
	<b>MO</b>	.761	.332	5.234	<b>.022</b>	2.139
	<b>EO</b>	.072	.315	.052	<b>.819</b>	1.075
	-2 Log likelihood		135.358			
	Cox & Snell R-square		.210			
	Nagelkerke R-square		.286			
<b>Radical Process Innovation</b>						
(industry dummy variables are included)						
	Firm age	-.016	.025	.381	.537	.985
	Firm size	-.342	.395	.751	.386	.710
	R&D intensity	.011	.020	.336	.562	1.011
	R&D personnel ratio	.023	.017	1.754	.185	1.023
	<b>MO</b>	-.442	.363	1.483	<b>.223</b>	.642
	<b>EO</b>	.743	.363	4.177	<b>.041</b>	2.101
	-2 Log likelihood		120.093			
	Cox & Snell R-square		.145			
	Nagelkerke R-square		.214			
<b>Radical Product Innovation</b>						
(industry dummy variables are included)						
	Firm age	.012	.023	.266	.606	1.012
	Firm size	-.627	.383	2.682	.102	.534
	R&D intensity	-.017	.020	.734	.392	.983
	R&D personnel ratio	.015	.017	.840	.359	1.016
	<b>MO</b>	-.596	.350	2.896	<b>.089</b>	.551
	<b>EO</b>	.930	.351	7.025	<b>.008</b>	2.533
	-2 Log likelihood		130.547			
	Cox & Snell R-square		.195			
	Nagelkerke R-square		.271			

All estimates are unstandardized coefficient

Figure 1 illustrates the interaction between MO and EO. The regression line indicating lower MO is steeper than that indicating higher MO, suggesting that EO improves SMEs' innovation performance to a greater extent when SEMs exhibits a lower level of MO. We can assume that the opposite is also true based on this figure. The positive impact of MO on SMEs' innovation performance will be greater when SMEs possesses a lower level of EO.

**FIGURE 1**

*Interaction Plot*

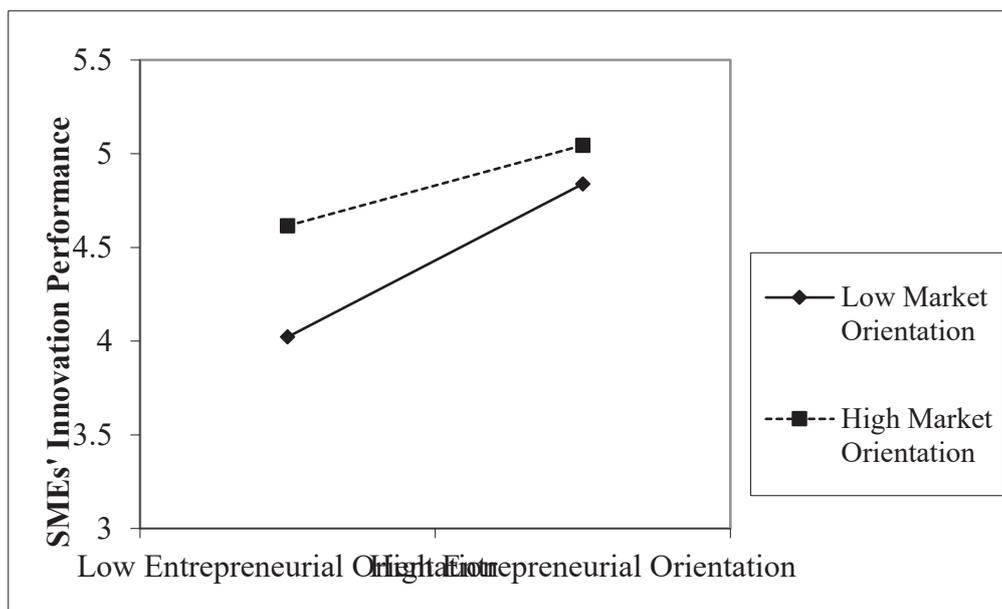


FIGURE 2

Logistic Regression Results for Types of Innovation

		Degree of Newness	
		Incremental Innovation	Radical Innovation
Target of Innovation	Process Innovation		EO(+)
	Product Innovation	MO(+)	EO(+) MO(-)

**DISCUSSIONS AND CONCLUSIONS**

This study investigates whether simultaneous pursuit of MO and EO attenuates firm's innovation performance improvement when firm has inherently strong commitment to technical innovation even though they are not large enough to conduct various innovative actions. We hypothesized interaction between MO and EO negatively impacts on SMEs' innovation performance improvement in terms of cost, quality, flexibility, and ROI improvement. In order to test our hypothesis, we collected survey data from 124 INNOBIZ certified Korean manufacturing SMEs and conducted the moderated regression analyses. And further, we performed logistic regression as post hoc analysis to explore the relationship between strategic orientation and types of innovation. Within this context, we make the following academic contributions.

First, we verified negative interaction effect between MO and EO on innovation performance improvement. When SMEs pursue both *EO and MO simultaneously*, the interaction effect on innovation performance turned out to be *disruptive rather than complementary*. Such simultaneous pursuit of MO and EO may not realize synergistic effects, but instead trigger competition for resource allocation, and incur conflicts or difficulties among business units in decision-making process or strategy implementation. Because each MO and EO requires different activities for innovation or different priorities in investments, employees in different business units have no choice but to compete for limited resources. That is to say, simultaneous pursuit of MO and EO increases complexities in implementation of innovation strategy due to lack of consensus about what should do first and which one is the most worthwhile (Voss & Voss, 2013). This tension or cultural conflict attenuates SMEs' innovation performance because most SMEs lack the necessary resources and capabilities to overcome that kind of difficulties (Humphreys et al., 2003; Baker & Sinkula, 2009).

Second, through our post hoc analysis, we found that each MO and EO has distinctive roles in innovation, and engenders different kinds of innovation. MO may encourage exploitative learning and in turn entails incremental innovation, while EO stimulates exploratory learning and generates radical innovation. Especially, our results that MO has positive impact on incremental product innovation and even has negative impact on radical product innovation at 10% significance level. It supports the limitations of MO which have mentioned in the previous studies (Li et al., 2008; Zhou et al., 2005; Atuahene-Gima & Ko, 2001). Our findings support arguments for dark side of MO on innovation. When firms with strong MO even they have high level of commitment to innovation, they may focus on product development which can make a quick profit because of 'tranny of the serving market' or 'learning myopia' (Levinthal & March, 1993; Frishammar & Horte, 2007; Li et al., 2006). And in essence, there is possibility that customer or competitor sense their

market changes incorrectly (Atuahene-Gima & Ko, 2001; Im & Workman, 2004). So, too much MO is rather negatively associated with radical innovation. Meanwhile, it is proved that firms with strong EO have a high probability of achieving radical process and product innovation. It corresponds to advantages of EO for innovation suggested previous literatures (Lumpkin & Dess, 1996; Zhou et al., 2005; Morgan et al., 2015; Zhou et al., 2005; Li et al., 2006; Morgan et al., 2015; Baker & Sinkula, 2009). And we addressed limitations of prior studies which neither consider nor classifies innovation performance based on its radicalness and objectives.

Our findings also suggest managerial implications and recommendations for SMEs managers. Firms need to recognize which types of innovation can be occurred and what can be achieved through innovation when they pursue each MO and EO, and decide their directions according to their innovation goals. Our findings suggest that ambidextrous innovation performance would not realize unless SMEs carefully manage and reduce such conflicts between MO and EO. If it is impossible, SMEs can foster or selectively utilize either MO or EO as a strategic capability depending on their business purpose and innovation strategy.

However, some limitations of our study also remain. First, this study only examines technical innovation but it is necessary to investigate the relationship between strategic orientation and administrative innovation to fully evaluate the effect of strategic orientation. And future studies need to consider other strategic orientation which affect SMEs' innovation. Second, disruptive interaction between MO and EO was revealed but potential sources of the negative interaction need to be further investigated. We need to explore potential moderating, mediating, or antecedent factors which influence the interactions of MO and EO, such as organizational structure or leadership types and so on. Third, this study is based on Korean manufacturing SMEs, but to increase external validity, future studies should broaden a sampling frame to multi-country samples. And future researchers could study how the effect of interplay between MO and EO in SMEs' is different from larger firms', using comparative data or collecting empirical data from both SMEs and large firms.

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# Alphabetical Authors Index

	Page No.		Page No.
<i>Blake, Jacqueline</i>	159	<i>Mao, Ning</i>	64
<i>Boon-itt, Sakun</i>	127	<i>Mun, Kwon Gi</i>	79
<i>Chang, Kuo-Chung</i>	215	<i>Nazir, Mohamed</i>	194
<i>Chang, Laurence F.K.</i>	231	<i>Nguyen, Thang N.</i>	1
<i>Chao, Pei-Ju</i>	50	<i>Novakova, Galia</i>	176
<i>Chen, Hsiao-Ling</i>	26	<i>Oh, Sungwoo</i>	244
<i>Chitta, Shyamsunder</i>	166	<i>Park, Hyun Jae</i>	255
<i>Choi, Gwang Jae</i>	244	<i>Park, Jihoon</i>	35
<i>Chun, Wootae</i>	123	<i>Park, Jin Hong</i>	35
<i>Fang, Shih-Chieh</i>	26	<i>Pavlov, Yuri</i>	176
<i>Fang, Yu-Hui</i>	183	<i>Rafique, Raza</i>	79
<i>Hamilton, John</i>	194	<i>Samaranayaked, Premaratne</i>	111
<i>Hsu, Hsuan-Yu</i>	238	<i>Sasaki, Masato</i>	9
<i>Hsu, Pei-Fang</i>	50	<i>Sheng, Tsai Yen</i>	231
<i>Hung, Wei-Hsi</i>	231	<i>Shishehgar, Majid</i>	159
<i>Jain, Ravi Kumar</i>	166	<i>Sim, Woojong</i>	123
<i>Kerr, Don</i>	159	<i>Siregar, Sessika</i>	215
<i>Kim, Hyojin</i>	272	<i>Somsuka, Nisakorn</i>	111
<i>Kim, Ju Hyeon</i>	255	<i>Spasov, Kamen</i>	176
<i>Laamrani, Anas</i>	9	<i>Supanchanaburee, Piyakarn</i>	127
<i>Laosirihongthongc, Tritos</i>	111	<i>Tee, Singwhat</i>	194
<i>Lee, Ji-Hyun</i>	144	<i>Thamsatitdej, Poomporn</i>	111
<i>Lee, Jung Hoon</i>	35, 244, 255	<i>Tsou, Hung-Tai</i>	238
<i>Lee, Su-Yol</i>	144	<i>Utting, Mark</i>	159
<i>Li, Chia-Ying</i>	183	<i>Wu, Cheng-Chung</i>	64
<i>Li, Eldon Y.</i>	231	<i>Yamashiro, Mitsuo</i>	9
<i>Lin, Cheng-You</i>	215	<i>Yang, Chiao-Yu</i>	202
<i>Lin, Chin-Feng</i>	202	<i>Zhao, Yao</i>	79



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