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CRITIQUE OF THE EMPIRICAL LITERATURE ON ENTERPRISE SYSTEMS—OVER A HALF DECADE OF RESEARCH

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ABSTRACT

The successful implementation and use of various enterprise systems (ES) has provoked considerable interest over the last few years. The purpose of this research study was to review a half decade of relevant dissertation literature in enterprise systems and outline the numerous issues, concerns, as well as benefits and challenges for this platform. This literature critique has been an attempt to provide synopses of relevant research pertaining to the enterprise systems literature. References included in this paper identify and address some of the most germane topics in enterprise systems. A quick look at today's job advertisements solidify that our future business graduates will be less likely to compete successfully or interview for the new positions without business process integration knowledge—discussed in this enterprise systems literature. Given the research findings, several conclusions, recommendations and a suggested list of future research topics for investigation are provided.

INTRODUCTION

The successful implementation and use of various enterprise systems (ES) has provoked considerable interest over the last few years. Management has recently been enticed to look toward these new information technologies as the key to enhancing competitive advantage. Replacing legacy IT systems with enterprise-resource-planning (ERP) systems or implementing new enterprise systems that can foster standardized processes--yet remain flexible enough to handle important variations in markets--are becoming a challenging task for many organizations.

The purpose of this study was to review recent relevant literature in enterprise systems and outline the numerous issues, concerns, as well as benefits and challenges for this platform. This paper is intended to provide the reader with quick summaries of significant research (not intended as all inclusive) that is representative of enterprise system literature. A major technique used for data analysis in this paper is meta-analysis which represents the quantitative summary of individual study findings across an entire body of research (Cooper and Hedges, 1994). Meta-

analysis is actually a form of second order research that comes after studies, and goes beyond primary study (Zhao, 1991).

The collection of studies was initiated by computerized searches of a specialized database, ProQuest's Dissertation Abstract and Dissertation Abstract International (DAI), covering the published doctoral dissertations from 2006 to 2011. The key words used were enterprise resource planning (ERP) systems, enterprise systems (ES), and enterprise information systems (EIS). The search was limited to articles in English language.

From the survey of the literature, the authors categorized the continually reappearing subtopics (related to challenges, hurdles as well as benefits) into categories: assessment, design/planning, evaluation/maintenance, education/maintenance, implementation, and strategy. The tabular and graphical representation of the categories is presented in the later section of this manuscript. The constructs streams studied in the literature are identified to provide an overall view of the research findings and conclusions related enterprise systems research area. The categories and constructs will provide useful implications and various perspectives to researchers and practitioners for the effective implementation and management of enterprise systems.

CRITIQUE OF THE ENTERPRISE SYSTEMS LITERATURE

Alnuaimi (2011) noted that modern organizations are increasingly implementing enterprise systems (ES) and that the potential benefits of these systems are encouraging. However, their failure rates are significantly high. This research develops a model linking cynicism toward ES with important system- and implementation- related antecedents and outcomes. The model examines how characteristics of the system and its implementation influence employee's cynicism toward the ES, and how such cynicism influences important system-related and psychological well-being outcomes.

Bala (2009) represented that implementation of an enterprise system (ES) often requires substantial changes to or reconfiguration of organizational business processes. Together, the new system and business processes may cause major changes in employees' work life. This dissertation makes important contributions by enriching our understanding of the impacts of ES implementations and associated business process changes on employees' work life. In terms of business practice, this work will help us develop effective interventions and change management strategies to maximize the success of ES implementations.

Ball (2008) stated that the primary focus of this research is to develop distributed decision policies that manage risk from multiple agent perspectives in a resource allocation system, and improve the overall performance utility for multiple agents and the system. The general approach used to govern these decisions is based on the concept of dynamic flexibility using options-based decision policies. The impact of managing system risk from a distributed decision-making perspective is evaluated with respect to improvements in both agent utilities and system properties while adhering to limited and finite capacity resource constraints.

Berente (2009) reports on an exploration of the interaction of standardized, linear, mechanistic enterprise information systems with the often pluralistic, nonlinear, organic contexts into which they are introduced. The goal of the research is to theorize about the causes and

effects of loose coupling between local practices and an enterprise system. This research also finds that incidents of loose coupling early in the implementation tend stabilize over time into states of loosely coupled equilibrium rather than into the tight alignment that is often assumed to be necessary for system success.

Bernadas (2008) focused on the perceptions of IT professionals in two countries as it pertains to factors that facilitate the maintenance of Enterprise Systems (ES). ES maintenance is a relatively recent concern among organizations and researchers. Some of the limitations that arose in this study were due to a lack of prior research on this topic. The results of this research will contribute to a better understanding of ES maintainability and will be of value not only to researchers but also to practitioners.

Bose (2009) argued that today's enterprise systems and networks are frequent targets of malicious attacks, such as worms, viruses, spyware and intrusions that can disrupt, or even disable critical services. A new behavioral approach is proposed for detecting emerging malware targeting mobile handsets. The approach is based on the concept of generalized behavioral patterns instead of traditional signature-based detection. The signature-based methods are not scalable for deployment in mobile devices due to limited resources available on today's typical handsets.

Chitnis (2009) stated that the implementation of distributed systems in a volatile enterprise environment always seems to be a difficult task to obtain. The motivation behind this thesis is the desire to understand the driving principles of SOA, and then apply those through a practical implementation, by addressing the challenges faced while implementing such a distributed enterprise system in the Electronic Discovery (E-Discovery) domain.

Curry (2009) illustrated in this study that REA creates a more flexible enterprise system needed both during implementation and throughout the evolution of an organization. Furthermore, REA enables an enterprise system to model an entire organization: a beneficial tool for upper management as well as lower-level employees. The author suggests that using a framework which focuses on business processes instead of an accounting schema, an enterprise system can have a foundation that better fits organizational needs.

Dorantes Dosamantes (2008) examines Top Management Team (TMT) characteristics and the contribution of Enterprise Information Systems (ES) to firm financial performance. A unique methodology based on recent accounting research is proposed to measure the long-term contribution of ES to financial performance. A theoretical model is developed to understand to what extent top management can influence the contribution of the ES to financial performance.

Garvey (2010) concluded that the research in this dissertation extends current practice in the management of risk for traditional systems and creates new constructs and protocols for the management of risk in engineering large-scale, complex, and highly networked enterprise systems. This work advances engineering management theory and analytic practice as applied to the measurement and management of risk for enterprise systems engineered within capability portfolio paradigms.

Gibbs (2011) illustrated that user participation in an ERP has benefit to the resultant information of an ERP. User participation and user influence have a positive relationship to information satisfaction with human resources (HR) information. The data retrieved from this

study is rich and varied and is both empirically sound and accessible to researchers and practitioners.

Guthrie (2008) described that information science research frequently seeks to discover the means by which practitioners can use information technologies (IT) to accomplish their goals. This research examines a possible relationship between design intent and fit: namely, how the designer's mental model of an enterprise system's intended use influences the design of the functionality and appearance of the application's component features. Using a positivistic case study methodology, mental models of intended use held by seven teams of enterprise system software developers were identified and classified.

Hassan (2010) introduces a logic-based, computer assisted framework for validating legal compliance of enterprise governance models. This framework is intended to help checking whether governance systems are consistent with the law. The framework proposes legal and enterprise models, a governance analysis method - called GAM -, in addition to a governance analysis language - called GAL-, and an implemented governance analysis tool - called GAT.

Helal (2009) stated that with the advances in the information and computing technologies, the ways the manufacturing enterprise systems are being managed are changing. More integration and adoption of the system perspective push further towards a more flattened enterprise. This research identified a need for new simulation modeling approaches that responds to the changing business environments towards more integration and flattened enterprise systems.

Holsing (2007) assessed perceptions of university business school leaders in the United States and Canada about the purposes, processes, challenges, and outcomes of the implementation of the SAP (software applications in programming) enterprise software solution within their institutions. This investigation gathered insights to implementation techniques and issues that had proved to be successful or disruptive, as well as those affecting program sustainability. Lastly, the study illuminated the outcomes of using an enterprise system to demonstrate integrated thought in higher education settings.

Ionescu (2009) noted that the Service Oriented Architecture (SOA for short) is becoming a de-facto standard paradigm for the design of the new generation of enterprise systems. The objectives of this thesis were to design a comprehensive regulatory mechanism for enterprise systems, which meets the challenges outlined above and to construct a prototype of this mechanism. The author called this mechanism ARM, for "A Regulatory Mechanism," (noting that one of the dictionary definition of the word "arm" is "power or authority" as in "long arm of the law").

Kamya (2010) examines an enterprise system appropriation process applying structuration theory and adaptive structuration theory (AST). The study presented key considerations for researchers seeking a critical engagement with structuration theory and its associated concepts to future enterprise systems research. In addition, the case study makes important suggestions for enterprise systems implementation practices. Goals for improved productivity, enhanced customer service, best practices, and process improvements are a high priority for many organizations. Failed enterprise resource planning (ERP) systems implementation due to the lack of understanding the interplay between institutionalized practice and other forces are

commonplace. The new model captures these relationships and makes public sector managers more aware of factors affecting successful implementations of ERP systems.

Klaus (2007) argued that user resistance is an important issue in the implementation of an Enterprise System (ES). However, despite the prevalence of user adoption literature, user resistance literature is scarce. This study examines user resistance at the individual level of analysis to determine the underlying reasons for user resistance, the types of resistant behaviors, and the management strategies to minimize resistance.

Kumar (2009) illustrated that implementing self-management for enterprise systems is difficult. This dissertation work introduces, implements, and evaluates i Manage, a novel system state-space based framework for enabling self-management of enterprise-scale systems. The system state-space, in i Manage, is defined to be a collection of monitored system parameters and metrics (termed system variables). In addition, from amongst the system variables, it identifies the variables of interest, which determine the operational status of a system, and the controllable variables, which are the ones that can be deterministically modified to affect the operational status of a system.

Lapham (2010) described that the Federal Government continues to implement enterprise systems (information and communication technology solutions) as part of reinvention and business transformation. Data analysis of digitally recorded interviews revealed seven interrelated themes of significance for public leaders shaping enterprise solutions and concomitant change. The underlying conclusion is the application of a full array of leadership competencies matters for successful assimilation of public enterprise systems: project management, organizational change, and effective communication among the more prominent aspects.

Mansour (2007) study illustrates the development of a novel software abstraction, termed isolation points (I-points), which can be used to isolate application components or subsystems from each other. The main contributions of this work are Isolation Points, which are software abstractions for monitoring and understanding dynamic runtime behaviors to better isolation application components hence, creating more robust distributed applications.

Marterer (2009) noted that case study research on enterprise systems in higher education organizations has shown that the challenges associated with implementing enterprise systems in higher education occur when unique organizational characteristics found in universities do not align with the standard characteristics built into the software programs. Based on such findings, the purpose of this study was to further explore the interaction between higher education organizations and enterprise systems during Enterprise Resource Planning (ERP) implementations in order to gain insight into the effects of ERP implementations in higher education.

Mi (2010) focuses on how to use knowledge of burstiness to develop new techniques and tools for performance prediction, scheduling, and resource allocation under bursty workload conditions. For multi-tier enterprise systems, burstiness in the service times is catastrophic for performance. New background scheduling schemes are designed to determine when and for how long idle times can be used for serving background jobs, without violating predefined

performance targets of foreground jobs. Extensive trace-driven simulation results illustrate that the proposed schemes are effective and robust in a wide range of system conditions.

Moss (2010) presents a framework for monitoring the dependencies between users, applications, and other system components, combined with the actual access times and frequencies. The author used operating system commands to extract information from the end-user workstations about the dependencies between system components. Also recorded were the times that system components were accessed, and data mining tools were used to detect usage patterns. The framework was designed to require minimal installation and management overhead, and to consume minimal system resources, so that it can be employed on a variety of enterprise systems, including those with low-bandwidth and partial-connectivity characteristics.

Mykityshyn (2009) investigates the dynamics that underlie enterprise performance, and takes a significant step toward showing how it might be predicted. In a novel approach, a comprehensive Enterprise System Architecture (ESA) is developed that introduces separate layers for strategic and operational processes, respectively. Results indicate that ESA maturity, the weighted summation of process maturity, information systems maturity, information technology maturity, and enterprise architecture maturity, is a good predictor of enterprise performance.

Southwick (2010) represents a 5½-year longitudinal case study of a process improvement initiative at a mid-sized American research university following implementation of an enterprise resource planning (ERP) system. The study addresses the question of how organizations, and more specifically, the IS function within organizations, are able to achieve enterprise integration following the implementation of enterprise systems. The study serves as a critical case in illustrating how individual and group-level conceptions of roles and organizational identity contribute to the elusive technical, process and social goals of enterprise integration following implementations of enterprise systems (ES).

Swartz (2006) stated that this case study monitored the use of an observation and feedback process and organizational citizenship behaviors during the implementation of SAP in a large telco that was undergoing radical change. It was found that the culture and behavior training fostered strong group cohesiveness to ultimately create the critical behaviors inventory for future teams deploying SAP.

Tatari (2009) concluded that attaining higher levels of system integration is seen as the primary goal of enterprise information systems in construction (CEIS). Increased system integration resulting from CEIS implementation is expected to lead to numerous benefits. This study quantifies the critical success factors that impact CEIS integration and the ensuing benefits. Furthermore, it analyzes the effects of system integration on CEIS induced benefits. It also investigates the impact of CEIS strategy on CEIS induced benefits, and identifies the relationship between CEIS strategy and system integration.

Thome-Diorio (2009) noted that when internal users value an enterprise business system, shared understanding of the vision the system will be effective and efficient and will meet organizational goals. These findings can be used to improve the alignment of the Air Force systems' value for the user and the enterprise, increase the transparency in IT transformations,

and enhance the effectiveness of enterprise system change initiatives, thus resulting in overall reduced business costs.

Wang (2008) aims to address the thorny issue of understanding exactly what it takes to foster the emergent use of enterprise systems in organizations in order to maximize the return on information systems investment. The findings advance our knowledge of emergent use and identify key factors for managers to formulate effective interventions for planned outcomes.

Worrell (2009) proposes that exploiting the significant investment in ERP requires developing organizational capabilities to enhance fit between system functionality and business needs. The findings suggest that common knowledge and liaison mechanisms are more critical to knowledge integration than are structural arrangements, and that knowledge integration is more important for organizational capabilities aimed at achieving change and innovation, rather than compliance and control.

Zhao (2007) examines ERP upgrade by identifying critical success factors that influence ERP upgrade success. The findings of this study indicated that (1) eight critical success factors are significantly correlated with ERP upgrade success; and (2) there are several significant critical success factors in each life cycle phase during ERP upgrade. Additionally, this study identified differences between initial ERP implementations and ERP upgrade projects.

SUMMARY AND CONCLUDING REMARKS

Table 1 presents the recent enterprise systems research by category and year and Figure 1 categorizes the publications by year as well as by author. The table and figure reveal that beginning in 2006, the number of studies in enterprise systems have increased dramatically from 2007 and continued to be the same until now, even though studies peaked in year 2009. Also, noteworthy is that the areas of interests are evenly spread in the entire categories with the highest showing in evaluation/maintenance.

Table 1
Subtopics of ERP Research by Year

Category/Year	2006	2007	2008	2009	2010	2011	Total
Assessment		1		1	3	1	6
Design/Planning	1	1		1			3
Evaluation/Maintenance			1	4	1		6
Education/Training		2	2	3	1	1	9
Implementation				1		1	2
Strategy			2	3	1		6
Total	1	4	5	13	6	3	32

Figure 1
Research Categories by Author and Timeframe

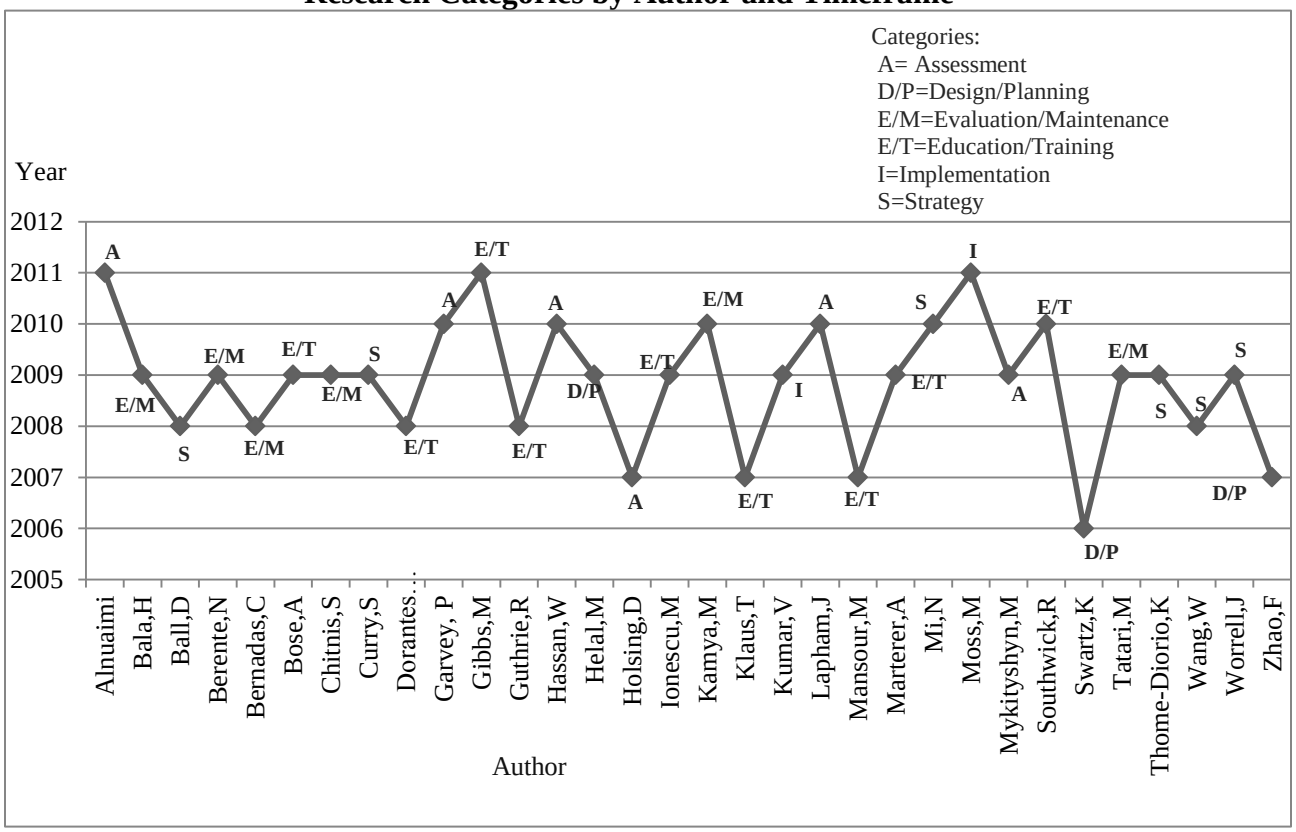

Table 2 outlines four construct streams identified from the literature: (1) finding factors determining successful enterprise systems implementation, design, and upgrade and maintenance, (2) outcomes and challenges of enterprise systems implementation, (3) strategic considerations of enterprise systems (especially, fit to organizational needs), (4) designing and implementing different types of enterprise systems. From the four construct streams, the authors noted that a very comprehensive research listing of topics in enterprise systems have emerged.

Table 2
Construct Streams of Research

Stream One: Critical Factors and Determinants of Successful Enterprise Systems	
Areas • Implementation • Design and planning • Upgrade • Maintenance	Factors (Individual, technological, and organizational) • Top management characteristics • Legal compliance • Process, IT, and enterprise architecture maturity • Effective communication • Project management • Cultural and behavioral factors • User and designer's perceptions • Intended usage • User involvement and participation

Stream Two: Outcomes and Challenges of ERP implementation	
Outcomes • Organizational changes • Business process improvement • System integration • Effects on higher education institute • Operational outcomes • Financial values (e.g., ROI) • Changes on employee's work life	Challenges • User resistance • Management risk • Multi-agent risk • System uncertainty • Managing malware • Behavioral isolation
Stream Three: Strategic Consideration: Fit to Organizational Needs	
• Fit between ERP functionality and organizational needs • Using process-oriented approach for better fitting • Fit between intended use and the design of ERP • Aligning organizational context to ERP systems	
Stream Four: Designing and Implementing Different Types of Enterprise Systems	
• Distributed enterprise system • Flattened enterprise system • Multi-tier enterprise system	

This literature critique has been an attempt to provide synopses of relevant research pertaining to the enterprise systems literature. References included in this paper identify and address some of the most germane topics in enterprise systems. The summative judgment and recommendation that the authors inferred on enterprise systems literature is that enterprise systems is very interdisciplinary in nature and a potentially fruitful research area. As in all reviews of this sort, the authors doubtlessly and inadvertently recognize that some important references may have been overlooked and perhaps others would code some of the studies differently. However, the researchers concur that the summary provides a wealth of findings related to the design, development and implementation of enterprise systems.

RECOMMENDATIONS AND FUTURE RESEARCH AGENDAS

With the advent of the Web many integrated business systems have now gained a Web interface which provides a rich research agenda for exploration. Secondly, Cloud Computing is an enterprise system initiative and emerging discipline which is changing the way corporate computing is and will be done in the future. This computing model for enabling convenient, on-demand network access to a shared pool of configurable computing resources that can be rapidly provisioned and released, is another relevant research area that could augment the educational community with theoretical frameworks, empirical studies, and practitioner experiences on enterprise systems in the Cloud. Issues related to change management, security, and processing approaches, associated with migrating to the cloud, are of paramount importance.

Interrelationships and links between the development of mobile applications (smartphones, tablets, 4G) and enterprise systems is an emerging research area. Enterprise software development has traditionally involved client-server applications that have effectively confined business information to enterprise desktops or VPN controlled access. With new options for

access, companies are developing processes to build and deploy applications to mobile phones. Developing enterprise mobile applications requires building applications according to specific corporate policies and configuring these applications so they integrate effectively with other enterprise systems.

Mobile application development brings the power of immediate information to a distributed, collaborative workforce, making information available on a device nearly every employee carries, to improve decision making, customer relationship management, as well as supply chain management. The validation and identification of the critical factors required to develop mobile applications and integrate with legacy business systems application development, especially security, end-user experiences, mobile device form factor, mobile operating system, mobile middle-ware and infrastructure demands of the business, are all topics for future study, as organizations strategically align their business processes with enterprise systems for competitive advantage.

A quick look at today's job advertisements solidify that our future business graduates will be less likely to compete successfully or interview for the new positions without business process integration knowledge—discussed in this enterprise systems literature. Our credibility, reputation and visibility as an institution of higher learning is at stake—given that the business student is not only our customer, but also our product. (Hunt, et al 2010). To survive in the new global, digital economy of ubiquitous computer networks, it is paramount that academicians re-engineer curriculum and update business core offerings that incorporate business process integration, project management, and the fundamentals of enterprise systems management—given the complexities of business operations.

The students will be the true beneficiaries—through internships and immediate job placements—if they are more knowledgeable of integrated business processes. Further educational research is essential and must be ongoing to ascertain the perceived, business process management competencies and skills needed by those entering the global workplace of multinational enterprises that have implemented integrated enterprise information systems.

REFERENCES

Alnuaimi, O. (2011*). Employee's reactions to enterprise systems implementations: the role of cynicism toward enterprise systems.* Unpublished doctoral dissertation, University of Arkansas.

Bala, H. (2009*). Nothing endures but change: Understanding employees' responses to enterprise systems implementation and business process change.* Unpublished doctoral dissertation. University of Arkansas.

Ball, D. (2008). *Managing multi-agent risk and system uncertainty using options-based decision policies.* Unpublished doctoral dissertation. University of Massachusetts Amherst.

Berente, N. (2009). *Conflicting institutional logics and the loose coupling of practice with NASA's enterprise information system.* Unpublished doctoral dissertation. Case Western Reserve University.

Bernadas, C. (2008). *Facilitating the maintenance of Enterprise Systems (ES): An exploratory study of perceptions of IT professionals in North America (Mexico and United States).* Unpublished doctoral dissertation.Texas A&M International University.

Bose, A. (2009). *Propagation, detection and containment of mobile malware.* Unpublished doctoral dissertation. University of Michigan.

Chitnis, S. (2009). *Service orientation: An evolutionary approach for designing a distributed enterprise E-Discovery system.* M.S. dissertation, California State University, Long Beach,

Cooper, H. and Hedges, L. (1994). *Handbook of Research Synthesis*. New York: Russell Sage Foundation.

Curry, S. (2009). REA: *A process-oriented approach to enterprise systems.* M.A. dissertation, Michigan State University.

Dorantes Dosamantes, C. (2008). *The influence of top management team characteristics on the contribution of enterprise information systems to long-term financial performance.* Unpublished doctoral dissertation. The University of Texas at San Antonio.

Garvey, P. (2010). *An analytical framework and model formulation for measuring risk in engineering enterprise systems: A capability portfolio perspective.* Unpublished doctoral dissertation. Old Dominion University.

Gibbs, M. (2011). *Evaluating user participation and user influence in an enterprise system.* Unpublished doctoral dissertation. Capella University.

Guthrie, R.(2008). *Audience directed models and software design: How developer mental models of users influence the design of enterprise system features.* Unpublished doctoral dissertation. The Claremont Graduate University.

Hassan, W. (2010). *Validating legal compliance: Governance analysis method.* Unpublished doctoral dissertation. University of Ottawa, Canada.

Helal, M. (2009). *A hybrid system dynamics-discrete event simulation approach to simulating the manufacturing enterprise.* Unpublished doctoral dissertation. University of Central Florida.

Holsing, D. (2007). *Integration of specialized disciplines in business school curriculum: Applying the SAP process.* Unpublished doctoral dissertation, University of South Dakota.

Hunt, C., Regan E., Everett D., Hunt D., & Becka P. (2010). *Information Systems Education Journal*, Integrating Enterprise Systems Concepts in the B-School—A Regional University Perspective, 8(9), ISSN: 1545-679X, http://isedj.org/8/9/

Ionescu, M. (2009). *A regulatory architecture for a digital enterprise.* Unpublished doctoral dissertation. Rutgers The State University of New Jersey - New Brunswick.

Kamya, M. (2010). *Developing an enterprise systems appropriation model in the public sector: A case study of implementing Payroll System Replacement (PAYSERV) at the New York*

State Office of the State Comptroller. Unpublished doctoral dissertation. State University of New York at Albany.

Klaus, Timothy Paul (2007). *An examination of user resistance in mandatory adoption of enterprise systems.* Unpublished doctoral dissertation, University of South Florida.

Kumar, V. (2009). *Enabling scalable self-management for enterprise-scale systems.* Unpublished doctoral dissertation. Georgia Institute of Technology.

Lapham, J. (2010). *Public leadership competencies in adoption of enterprise systems at Federal Government institutions*. Unpublished doctoral dissertation. University of Phoenix.

Mansour, M. (2007). *Behavior isolation in enterprise systems.* Unpublished doctoral dissertation. Georgia Institute of Technology.

Marterer, A. (2009). *Enterprise resource planning in higher education: A comparative case study.* Unpublished doctoral dissertation. University of North Florida.

Mi, N. (2009). *Dependence-driven techniques in system design.* Unpublished doctoral dissertation. The College of William and Mary.

Moss, M. (2010). *Assessing operational impact in enterprise systems with dependency discovery and usage mining.* Unpublished doctoral dissertation. Georgia Institute of Technology.

Mykityshyn, M. (2009). *Assessing the maturity of information architectures for complex dynamic enterprise systems*. Unpublished doctoral dissertation. Georgia Institute of Technology.

Southwick, R. (2010). *Enterprise thinking role transitions in enterprise system process improvement teams.* Unpublished doctoral dissertation. Syracuse University.

Swartz, Kathleen S. (2006). *A participatory action research study to determine the effects of an observation and feedback process and organizational citizenship behaviors during implementation of SAP*. Unpublished doctoral dissertation. Golden Gate University.

Tatari, M. (2009). *Empirical analysis of construction enterprise information systems: Assessing the critical factors and benefits.* Unpublished doctoral dissertation. University of Maryland.

Thome-Diorio, K. (2009). *Air Force users' perceptions of the value of information technology-enabled enterprise business systems.* Unpublished doctoral dissertation. Walden University.

Wang, W. (2008). *Emergent use of enterprise systems by employees: Exploring the human side.* Unpublished doctoral dissertation, Hong Kong Polytechnic University.

Worrell, J. (2009). *Running the ERP marathon: Enhancing ERP-business fit in the post-implementation phase.* Unpublished doctoral dissertation. The Florida State University.

Zhao, F. (2007). *An empirical study of enterprise system upgrades.* Unpublished doctoral dissertation. The University of Nebraska – Lincoln.

Zhao, S. (1991). Meththeory, Metamethod, Meta-Data-Analysis: What, Why, and How? *Sociological Perspectives* (34:3), 377-390.

CONSTRUCTING VIRTUAL COMMUNITIES ON INTERNET: A RESEARCH MAP THROUGH DIFFERENT ORGANIZATIONAL LEVELS

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ABSTRACT

Virtual communities have become an important subject for academics and practice. However, relevant researches seem divergent which is bad for knowledge development and business practice. The purpose of this article is to integrate previous studies about the virtual community and propose a framework which enables a better dialogue among academics and practitioners. We review and classify the relevant published papers from 1997 to 2009 in terms of various analytic levels. Three analytic levels are identified, namely individual, group and community level. A specific research map is then sketched for each analytic level by which researchers and practitioners know where to start with for future research. Finally, we address some possible research directions in discussion and conclusion.

INTRODUCTION

Since information technology has made huge progress in recent years, one of the most impressive changes is the transformation of interpersonal communication. Previous studies mention that information technology has generated a new communication style—computer-mediated communications (CMC, hereafter)—to impact interpersonal communications (Rice 1980). CMC refers to a group of people who communicate each others by computer media, like email or internet. Against CMC, the face-to-face communication (F2F, hereafter) is a more traditional communication style. Though F2F has some characteristics better than CMC, Etzioni & Etzioni (1999) consider that CMC has superior broadcasting ability than F2F does. CMC could enable every member in a group to communicate with each other simultaneously. Except broadcasting ability, memory is also one of the significant merits of CMC as opposed to F2F. The former could maintain a more effective memory than the latter (Etzioni & Etzioni 1999).

Because of fast development in communication technology, computer media become a popular communication tool. This phenomenon generates several new terminologies of which one is called virtual community meaning the interpersonal relationship in a group virtualized through using computer media. In fact, the concept of community originates from sociology that refers to a social group linked by tight knit or an aggregate of people who know each other well (Etzioni & Etzioni 1999). The original definition of community is useful for us to define a virtual community and would be discussed in the next section.

That people who communicate with each others and maintain their relationship by CMC is a popular alternative to others, for example, mail or F2F. Today, we can see more and more virtual communities so innovative and powerful for the whole society. Because of its huge

influence for the individual and society, researchers from many fields have paid far more attention to address this issue by studying communication, e-commerce and consumer behavior. However, according to Li (2004), the research about virtual community so far is too divergent. A clear research map of virtual community is needed to guide future research, and this is what we want to address in this article. In doing so, both scholars and practitioners are able to communicate well under the jargon of virtual community, and we will find more effective ways to develop and sustain it.

We divide this paper into six sections. The first is introduction which presents the importance of the literature integration. Second, we accommodate the concept of community from sociology and move on to address virtual communities. Third, three analytic levels are categorized and presented. In the forth section, related articles are reviewed and discussed. In the fifth and final section, we draw the research map, classify issues for each analytic level, and point out further research direction for virtual communities.

EVOLUTION OF COMMUNITY CONCEPT: SOCIOLOGY, COMPUTER-MEDIATED COMMUNICATION, INTERNET TECHNOLOGY

Original concept of communities: sociology perspective

The concept of communities could be traced back to Tönnies' (1967) concept for community (Gemeinschaft). While both community and society refer to an aggregation of people, Tönnies argues that community is different from society (Gesellschaft) in terms of its intimate, private, and exclusive living together. Their difference is public or not. In other words, the community is not as public as society. By Tönnies' definition, community could be divided into three categories. The first is community by kinship where people are linked by kinship as a community. The second is community of locality, and the third is community of mind.

The other classification of communities against Tönnies' (1967) was proposed by Gusfield (1975). Gusfield (1975) divides the communities into geographic communities and relational communities. Geographic communities mean neighborhood, town or region which is the same as the community of locality proposed by Tönnies. Relational communities are similar to the community of mind proposed by Tönnies which denotes an aggregation of people linked by their own interest. Kinship and mind could be treated as factors which could connect people together, so it is part of the relational communities proposed by Gusfield. By synthesizing the previous concepts proposed by Tönnies and Gusfield, we could find the traditional community has two components in common, including an aggregation of people and invisible relationship among members.

Virtual communities: computer-mediated communication

In general, a group of people who communicate everyone by computer media could be treated as a virtual community (Romm, Pliskin & Clarke 1997). In literature, scholars define virtual communities with different perspectives. Some researchers define virtual communities from its' metaphysical properties (Rothaermel & Sugiyama 2001). Falk (1998) defines virtual

communities by their shared goals and ideals, degree of stability, growth, loyalty and commitment. Rothaermel & Sugiyama (2001) consider the virtual community is similar to a community of mind proposed by Tönnies (1912, 1967).

Other scholars define virtual communities from practical perspectives and focus on typology of virtual communities (Bagozzi & Dholakia 2002; Wellman & Gulia 1999; Hagel & Armstrong 1997). Wellman & Gulia (1999) regard virtual communities as consumer groups that interact with others on the internet exchanging personal goals. Hagel & Armstrong (1997) share the same perspective with Wellman & Gulia (1999) and divide virtual communities into four types—(1) community of transaction (2) community of interest (3) community of fantasy and (4) community of relationship. That is to say, the virtual community users (consumers) interact with others online for purposes which are transaction, interest, fantasy or relationship building.

A whole virtual community on a website: internet technology

Members of the virtual community use computer-mediated communications to replace the F2F communication for repeated interpersonal communication. That is the early definition of virtual community is not so clear about the boundary of a virtual community. Today, Internet has been one of most popular and powerful communication mediates we ever use, and it enables us to build virtual community and clarify its boundary.

Fernback and Thompson (1995) provide a much more clear definition of virtual community, which is "social relationships forged in cyberspace through repeated contact within a specified boundary or place (e.g., a conference or chat line) that is symbolically delineated by topic of interest." Their definition has mentioned about the concept of cyberspace, boundary and interest, and the boundary is one of the important concepts ever since.

Fernback and Thompson (1995) consider the topic of interest discussed in community is the dimension to define the virtual community in cyberspace. Though the topic could define the boundary of virtual community, we argue that the web services provided by a website manager could facilitate the formation of virtual community within an obvious boundary. When users like to use a new service or discuss a new topic on a website, they usually need to register first and then get permission to use the website service. After a long period of time, users would normally perceive high switching costs and settle to the website which he or she often used. (Mahadevan 2000). The website could gradually foster a whole virtual community with a clear identity and boundary. Once the identity is so clear, website managers can easily target and manage it.

That is the feasibility of fostering a virtual community enables business managers to utilize the virtual community to support business strategy. Researchers who research about user behavior on Internet have observed that members on a website through creations, sharing, collaboration and recreation provide huge benefits to all users (Hall & Graham 2004; Ma & Agarwal 2007). This could be seen as a new value creation model that could benefit all players including the business itself. For the purpose of profit making, how to successfully build a virtual community would be one of the major challenges for business managers. Many researchers have made efforts to study relevant issues about virtual communities. These researches need to be integrated in order to draw some more research implications which we aim to achieve in this article.

A FRAMEWORK TO UNDERSTAND VIRTUAL COMMUNITY RESEARCH

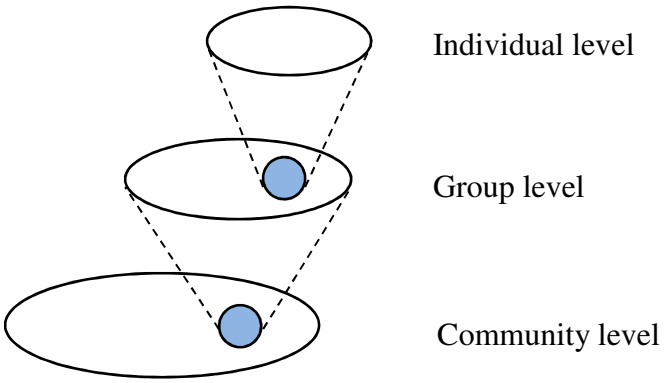
Rothaermel and Sugiyama (2001) develop theories about virtual community at two levels, individual and community level, dealing with different issues. Their individual level study focuses on what motivates individuals to engage in transactions within a virtual community; community level focuses on what characteristics of virtual community result in commercial success.

Dholakia, Bagozzi and Pearo (2004) distinguish two different types of virtual communities which are network-based and small-group-based. By their definition, the member in a network-based virtual community is without personal knowledge about other members, such as the one in Amazon.com; individual members in a small-group-based virtual community would have known everyone very well in persons. Taking the software developer community as an example, users may make an appointment with specific members to discuss new concepts or learn new skills.

Dholakia, Bagozzi and Pearo (2004) find the virtual community type as a significant moderator for users' participation. The utmost difference between these two kinds of virtual communities is whether members have relationship with others. The network-based virtual community proposed by Dholakia, Bagozzi and Pearo (2004) is similar to the early definition of virtual communities. The small-group-based virtual community would be between individual and community level. Integrating Rothaermel and Sugiyama's (2001) and Dholakia, Bagozzi and Pearo's (2004) research, we could identify three analytic levels of virtual community; namely individual, group and community level. This is useful for understanding and constructuring the research map of virtual communities.

With regard to previous literature, we identify three analytic levels in virtual community research—individual, group and community level. Individual level research means that the researcher conducts a study based on individual members or users' behavior in a virtual community. Group level researches indicate that the researcher takes each group as analytic units and constructs relevant theory for virtual community issues. Community level research shows that the researcher conducts a research aiming for the whole community phenomena or relationship between two communities. In what follows, we delineate three levels of researches in literature and examine research issues.

Figure 1 Three analytic levels of a virtual community



DATA COLLECTION

We collect research articles about virtual communities from SCIE database (Science Citation Index Expanded). In total, 51 academic research papers are collected from SCIE database from 1997 to 2013. These papers are reviewed, categorized and fit in a framework of three analytic levels. Each research in separate specific analytic level would be further classified into a research issue, and then a research map for each analytic level would be gradually formed and presented.

A descriptive statistics of collected articles is shown as Table 1. Obviously, the group level research only accounts for 8% of all collected articles, the least percentage of the literature we reviewed.

Table 1
A DESCRIPTIVE STATISTICS OF COLLECTED ARTICLES

ANALYTICAL LEVEL	NUMBER OF ARTICLES	PERCENTAGE	YEARS
INDIVIDUAL LEVEL	34	52%	2002-2013
GROUP LEVEL	5	8%	2001-2013
COMMUNITY LEVEL	26	40%	1997-2013
TOTAL	65	100%	

A RESEARCH MAP OF EACH ANALYTIC LEVEL

Individual level

Individual level researches focus on members' behavior in a virtual community. It has several main issues in this category that has been addressed by scholars. In the individual level research, we identify four main research streams for virtual community research. These issues are members' participation intention, loyalty intention, sharing intention and creation & recreation.

Because participation is the first step for initiating a virtual community, participation intention is a really important issue for building virtual community in which many researchers have addressed (Lin 2006; Song & Kim 2006; Bock, Ng & Shin 2008; Wu & Tsang 2008; Nantel & Sekhavat 2008; Cavaglion 2008; Zhao, et al. 2012; Sun, et al. 2012; Tsai & Pai 2013). Other three issues are established only when virtual community is initiated successfully.

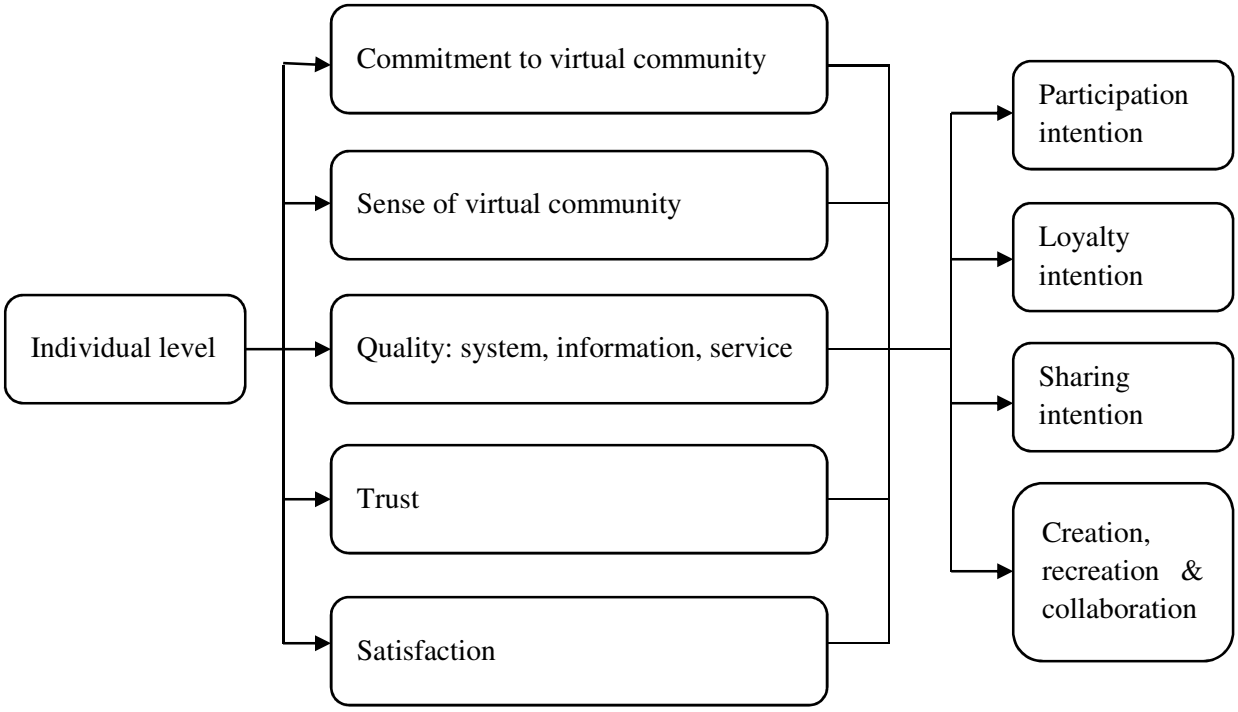
After we initiate a virtual community, how to retain members becomes critical, especially for researchers who study loyalty intention (Kardaras, Karakostas & Papathanassiou 2003; Shang, Chen & Liao 2006; Lin 2008; Jang, et al. 2008; Lin, et al. 2008; Lin 2009; Casaló 2010). Visit frequency similar to loyalty has also been studied (Valck, et al. 2007).

Sharing intention that usually means the knowledge sharing is also the key issue in virtual community research which many scholars have focused on (Koh & Kim 2004; Chiu, Hsu & Wang 2006; Hsu, et al. 2007; Ma & Agarwal 2007; Young & Tseng 2008; Cheung & Lee 2009; Suh 2013). Knowledge sharing behavior could accumulate large database to help members solve many problems they encounter at work. Virtual community provides a low cost avenue to

support each others. Davenport and Prusak (1998) consider that the knowledge sharing is unnatural since members think their knowledge is important and valuable. There is a gap between real behavior and manager expectation. Sharing intention becomes an important research issue in virtual community resulting from this gap. Though the individual sharing could increase knowledge capital, the collaboration would be the other crucial source of knowledge accumulation (Bagozzi & Dholakia 2006). Collaboration issue has been paid attention by business management, especially when managers apply the virtual community within organization to meet their strategic goal (Hall & Graham 2004).

Several factors would cause these four behavior intentions and they also could be an independent research topic. The literature shows that some factors have been treated as the main factors that affect the member behavior intention from motivational perspective (Hsu & Lu 2007). Others important factors are commitment to virtual community (Jang, et al. 2008), sense of virtual community (Koh & Kim 2003; Blanchard 2008; Tonteri, L., et al. 2011), quality (system, information and service) (Lin 2008), trust (Wu & Tsang 2008; Ridings, Gefen & Arinze 2002; Zhang, et al. 2010; Wu, et al. 2010; Lu, et al. 2010) and satisfaction (Lin 2008; Valck, et al. 2007). We construct the research map as Figure 2.

Figure 2 A research map of individual level



Group level

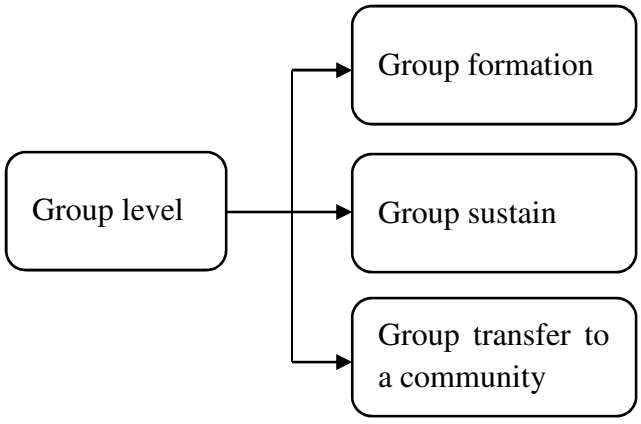
The group would be the predecessor of a virtual community. The literature about the virtual group is rare compared to individual and community level research. We believe that the main reason is it's very difficult to differentiate a group from others in a virtual community, and

community level in particular. Yu & Young (2008) point out that a community creates the norm and culture for group members who interact with each member for specific goals that are either shared in the group or among members. In other words, the community embraces several groups which contain strong relationship between group members, and the community members are not well familiar with every member but interact within a shared norm and culture.

Important issues about virtual groups that we identify from previous studies are group formation process (Phoenix & Neil 2008; Rullani & Haefliger 2013), group sustain (Yu & Young 2008; Dholakia, Bagozzi & Pearo 2004), transformation process from group to community (Kling & Courtright 2003). In the group formation stage, Phoenix & Neil (2008) have identified seven types of group identities that would influence group formation from a real "virtual group" in Taiwan. These group identities are affection, alliance, attachment, bonding, closeness, kinship and nostalgia. They find that both alliance and kinship would drive the group formation. That is the group identities play an important role at the group formation stage.

Wessner & Pfister (2001) consider the group formation process consists of three phases: initiating, identifying and negotiation. Any member could be an initiator for current problem he or she faces. Then initiator would identify who fulfill the requirement to solve problems, initial group would be formed after identifying stage. Through the negotiation between members which is the critical stage to group sustains, members' relationship would be built gradually as time goes on and members would support each others. In the literature, both social supports and group norm are conducive to members' participation for group (Phoenix & Neil 2008; Dholakia, Bagozzi & Pearo 2004), and the group is sustained. Except behavior study, some scholars focus on system design to improve the human relationship sustain in a group through computer-mediated communication (e.g. Hishian, Okada & Suzuki 2005). When more and more people participate in the group, group will transfer to a community (Kling & Courtright 2003). Only few researches talk about issues of group sustained and transformation which are both underdeveloped field. We constructed the research map of group level as Figure 3.

Figure 3 Research map of group level



Community level

As Li (2004) argues, the virtual community study is too divergent; this statement is even more genuine on community level research. In community level research, the relevant issues contain the research methodology (Hair & Clark 2007; Ward 1999; Illum, et al. 2010; Abfalter, D., et al. 2012), member relationship (Marshall 2000; Castelfranchi & Tan 2002; Cindio, et al. 2003; Carter 2004), sustaining community (Leimeister, Sidiras & Krcmar 2006; Lin 2007; Lin & Lee 2006; Teo, et al. 2003; Hsiao & Chiou 2012), economic leverage (Balasubramanian & Mahajan 2001), knowledge distribution (Koh & Kim 2004; Lin & Hsueh 2006; Chen, et al. 2012; Hung & Cheng 2013) and interaction with other communities (Gu, et al. 2007) and society (Agres, Edberg & Igbaria 1998; Romm, Pliskin & Clarke 1997).

According to the literature we collected from SCIE database, methodology issue in community level seems to get more attention than the other two analytic levels. So we divide these issues in community level into two categories which are theory building and methodology. The purpose of theory building is construction of theory to explain the phenomena in a virtual community, and methodology talks about how to approach the community level research. For more systematic understanding of community level research, we classify the community level research issues in terms of the boundary that distinguishes what happens inside or outside. Issues within the virtual community comprise member relationship, knowledge distribution, sustaining community and economic leverage, while issues that happened outside the virtual communities are interaction with the whole society and with other virtual communities. These research issues are structured and demonstrated below.

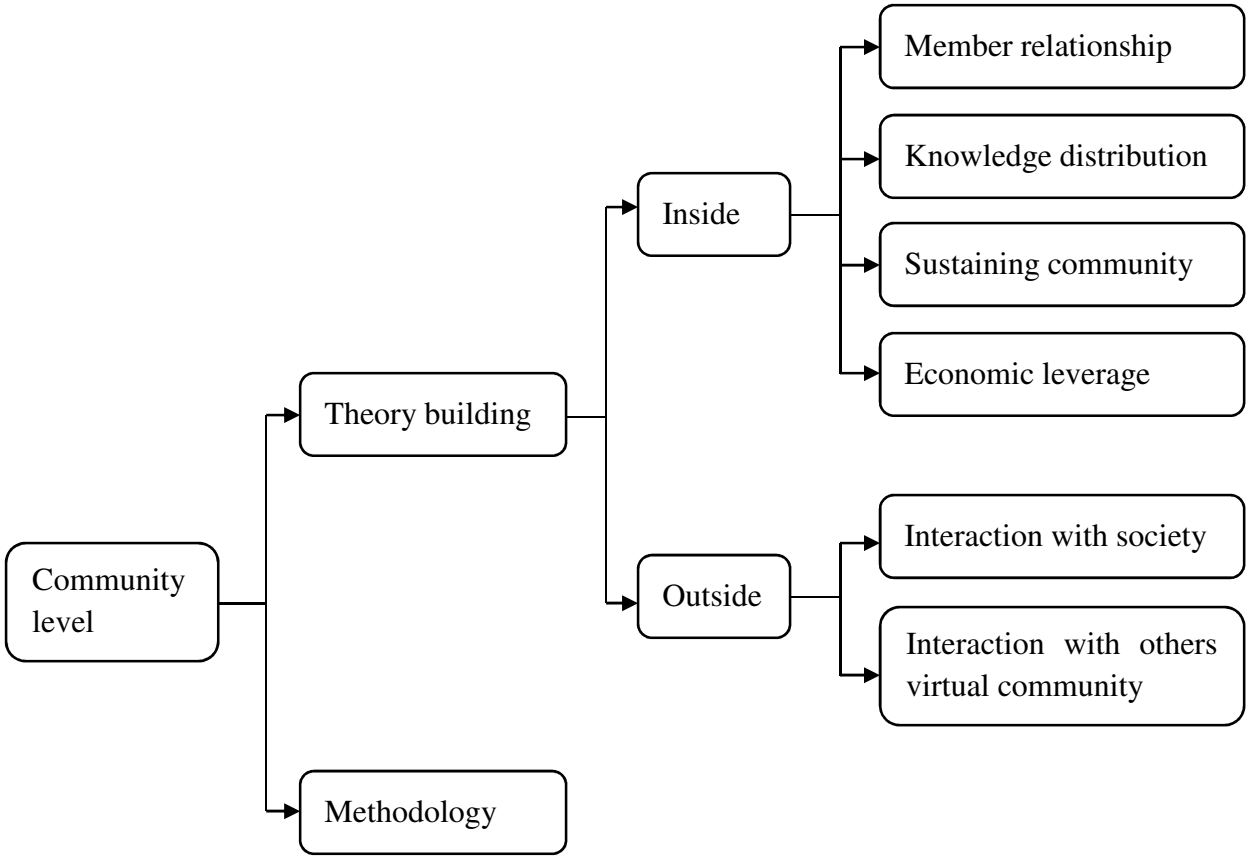
As for methodology, Ward (1999) thinks that the ethnography is one of the most appropriate tools in virtual community research because it allows participation of virtual community to define their own reality and parameters. Besides the merit of interpretative depth, community level research would be limited by sample size when we use the quantitative method to build theories. Qualitative methods, as the ethnography, not only have merit on the sample size issue against quantitative method, but also could more deeply understand phenomena that happened in virtual community especially about culture issue (Hair & Clark 2007). Following the advancement of methodology, other issues, such as ethics of ethnographics in internet context, has been discussed by Hair & Clark (2007).

The inside phenomenon, member relationship (Carter 2004) and knowledge distribution (Koh & Kim 2004; Lin & Hsueh 2006; Hersberger, Murray & Rioux 2007), is different from individual level behavior, and it is more of a macro-perspective such as the social network analysis. In our literature, there is no such kind of research that applies the social network analysis so far, but we think that is a critical research direction to help us further understands community management. Sustaining community issue discusses the factors which would influence whether virtual community succeeds. Previous studies have referred to some factors that would affect the performance of a virtual community management that concludes platform building (Pan & Lan 2009), the information accessibility and community adaptivity (Teo et al. 2003), online and offline activities (Lin 2007), regulation and right (Chua 2009; Suzor 2009), social capital (Mathwick et al. 2007) etc. Economic leverage (Balasubramanian & Mahajan 2001;

Porter & Donthu 2008) is an important issue when we apply virtual communities to business, but we still need to make more efforts in exploring something unknown.

Across boundaries of the virtual community, a virtual community would interact with two targets, other virtual communities and the whole society. Obviously, two interaction forms are competition with other virtual communities (Gu et al. 2007) and influence or to be influenced by the society where it is embedded. These two interaction forms would impact the growth and state of the virtual community, and they are also important and worth further discussion. The research map of virtual communities at community level would be constructed as Figure 4.

Figure 4 Research map of community level



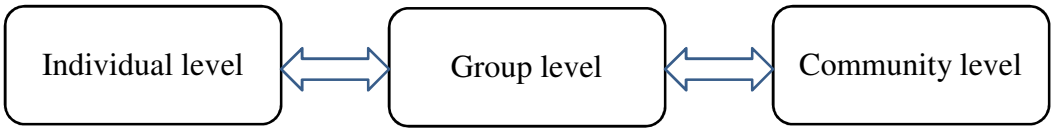
DISCUSSION AND CONCLUSION

This study reviews and integrates previous literature to construct different analytic levels for virtual community research. We identify three analytic levels in the research of virtual community and clarify specific research issues for each analytic level.

Though the analytic level perspective could highlight the research issue more clearly, lack of the connection between levels is the main concern for framework completeness. We suggest that the connection between different levels could be built by two perspectives, development of process of time sequence and cross level analysis, which are illustrated later.

One of the important issues in virtual community research is the process of building virtual community that we have not referred (Plisking & Romm 1997; Dennis et al. 1998). We suggest that the process of virtual community building should begin from a person who demonstrates leadership and enthusiasm (individual level), and then a group gradually emerges (group level). Through the increase of member size and the growth of group, the group will transfer to a community that is an aggregation of subgroups with its shared culture and norm (Latang & Bourgeois 1996). Under the shared culture and norm within the community, the member behavior (individual), group and community would influence to other two levels. Finally, the community would converge to a stable state. Individual, group and community interaction is demonstrated as Figure 5.

Figure 4 Interaction between different analytic levels



The cross level analysis is also a crucial methodology issue in studying virtual community research such as the organization research (Meyer, Tsue & Hinings 1993; Klein, Dansereau & Hall 1994). Nowadays, researchers use the individual level variable to understand members' behavior, the group level variable to predict group level phenomena. Because individual should be embraced by group and community, group and community level variables would influence members' behavior as well. For understanding relationship of variables cross level, we should further discuss how to collect and analyze data. This issue would emerge in each pair of three levels (I-G, G-C, I-C).

In recent years, the phenomena of virtual community have been heeded by researchers. It is because the virtual community has powerful influence to the business and society. Because the result of previous studies seems mixed and divergent, we provide a framework and try to demonstrate the current research state. All in all, the researcher, with help of this study, could easily identify the research gap by each analytic level we proposed, connection between levels and development process of virtual community. Through this three-level framework, future research works in virtual community would speak the same language which allows us to compare and contrast different ideas in order to build our knowledge about it.

REFERENCES

Abfalter, D., et al. (2012). Sense of virtual community: a follow up on its measurement. *Computers in Human Behavior, 28*(2), 400-404.

Agres, C., D. Edberg & M. Igbaria (1998). Transformation to virtual societies: forces and issues. *The Information Society, 14*(2), 71-82.

Bagozzi, R. P. & U.M. Dholakia (2002). Intentional social action in virtual communities. *Journal of Interactive Marketing, 16*(2), 2-21.

Bagozzi, R.P. & U.M. Dholakia (2006). Open source software user communities: a study of participation in Linux user groups. *Management Science, 52*(7), 1099-1115.

Balasubramanian, S. & V. Mahajan (2001). The economic leverage of the virtual community. *International Journal of Electronic Commerce, 5*(3), 103-138.

Blanchard, A (2008). Testing a model of sense of virtual community. *Computers in Human Behavior, 24*(5), 2107-2123.

Bock, G. W., W.L. Ng & Y.H. Shin (2008). The effect of a perceived leader's influence on the motivation of the members of nonwork-related virtual communities. *IEEE Transactions on Engineering Management, 55*(2), 292-303.

Carter, D. (2004). Living in virtual communities: making friends online. *Journal of Urban Technology, 11*(3), 109-125.

Casaló, L.V., C. Flavián & M. Guinalíu (2010). Rlationship quality, community promotion and brand loyalty in virtual communities: evidence from free software communities. *International Journal of Information Management, 30*(4), 357-367.

Castelfranchi, C. & Y.H. Tan (2002). The role of trust and deception in virtual societies. *International Journal of Electronic Commerce, 6*(3), 55-70.

Cavaglion, G. (2008). Voices of coping in an Italian self-help virtual community of cyberporn dependents. *Cyberpsychology & Behavior, 11*(5), 599-601.

Chen, Y.J., Y.M. Chen & M.S. Wu (2012). An empirical knowledge management framework for professional virtual community in knowledge-intensive service industries. *Expert Systems with Applications, 39*(18), 13135-13147.

Cheung C.M.K. & M.K.O. Lee (2009). Understanding the sustainability of a virtual community: model development and empirical test. *Journal of Information Science, 35*(3), 279-298.

Chiu, C.M., M.H. Hsu & E.T.G. Wang (2006). Understanding knowledge sharing in virtual communities: an integration of social capital and social cognitive theories. *Decision Support Systems, 42*(3), 1872-1888.

Cindio, F.D., O. Gentile, P. Grew & D. Redolfi (2003). Community networks: rules of behavior and social structure. *The Information Society, 19*(5), 395-406.

Davenport, T.H. & L. Prusak (1998). *Working knowledge: how organizations manage what they know.* Boston, Harvard Business School Press.

Dennis, A.R., S.K. Pootheri & V.L. Natarajan (1998). Lessons from the early adopters of web groupware. *Journal of Management Information Systems, 14*(4), 65-86.

Dholakia, U.M., R.P. Bagozzi & L.K. Pearo (2004). A social influence model of consumer participation in network- and small-group-based virtual communities. *International Journal Research in Marketing, 21*(3), 241-263.

Etzioni, A. & O. Etzioni (1999). Face-to face and computer-mediated communities: a comparative analysis. *The Information Society, 15*(4), 241-248.

Falk, J. (1998). The meaning of the web. *The Information Society, 14*(4), 285-293.

Fernback, J. & B. Thompson (1995). Virtual communities: abort, retry, failure? from http://www.well.com/user/hlr/texts/VCcivil.html

Gu, B.P., B.R. Konana & H.W. Chen (2007). Competition among virtual communities and user valuation: the case of investing-related communities. *Information Systems Research, 18*(1), 68-85.

Gusfield, J. (1975). *Community: a critical response.* New York, Harper & Row.

Hagel, J. & A.G. Armstrong (1997). *Net gain: expanding markets through virtual communities.* Boston, Harvard Business School Press.

Hair, N. & M. Clark (2007). The ethical dilemmas and challenges of ethnographic research in electronic communities. *International Journal of Market Research, 49*(6), 781-800.

Hall, H. & D. Graham (2004). Creation and recreation: motivating collaboration to generate knowledge capital in online communities. *International Journal of Information Management, 24*(3), 235-246.

Hersberger, J.A., A.L. Murray & K.S.R. Rioux (2007). Examining information exchange and virtual communities: an emergent framework. *Online Information Review, 31*(2), 135-147.

Hishian, M., R. Okada & K. Suzuki (2005). Group formation for web-based collaborative learning with personality information. *International Journal on E-learning, 4*(3), 351-364.

Hsiao, C.C. & J.S. Chiou (2012). The effect of social capital on community loyalty in a virtual community: test of a tripartite-process model. *Decision Support Systems, 54*(1), 750-757.

Hsu, C.L. & H.P. Lu (2007). Consumer behavior in online game communities: a motivational factor perspective. *Computers in Human Behavior, 23*(3), 1642-1659.

Hsu, M.H., T.L. Ju, C.H. Yen & C.M. Chang (2007). Knowledge sharing behavior in virtual communities: the relationship between trust, self-efficacy, and outcome expectations. *International Journal Human-Computer Studies, 65*(2), 153-169.

Huang, C.E. (2009). Why do virtual communities regulate speech? *Communication Monographs, 76*(2), 234-261.

Hung, S.W. & M.J. Cheng (2013). Are you ready for knowledge sharing? An empirical study of virtual communities. *Computers & Education, 62*, 8-17.

Illum, S.F., S.H. Ivanov & Y. Liang (2010). Using virtual communities in tourism research. *Tourism Management, 31*(3), 335-340.

Jang, H.Y., L. Olfman, I. Ko, J. Koh & K. Kim (2008). The influence of on-line brand community characteristics on community commitment and brand loyalty. *International Journal of Electronic Commerce, 12*(3), 57-80.

Kardaras, D., B. Karadostas & E. Papathanassiou (2003). The potential of virtual communities in the insurance industry in the UK and Greece. *International Journal of Information Management, 23*(1), 41-53.

Klein, K.J., F. Dansereau & R.J. Hall (1994). Levels issues in theory development, data collection, and analysis. *Academy of Management Review, 19*(2), 195-229.

Kling, R. & C. Courtright (2003). Group behavior and learning in electronic forums: a sociotechnical approach. *The Information Society, 19*(3), 221-235.

Koh, J.H. & Y.G. Kim (2004). Knowledge sharing in virtual communities: an e-business perspective. *Expert Systems with Applications, 26*(2), 155-166.

Koh, J. & Y.G. Kim (2003). Sense of virtual community: a conceptual framework and empirical validation. *International Journal of Electronic Commerce, 8*(2), 75-93.

Leimeister, J. M., P. Sidiras & H. Krcmar (2006). Exploring success factors of virtual communities: the perspectives of members and operators. *Journal of Organizational Computing and Electronic Commerce, 16*(3-4), 279-300.

Latang, B. & J.M. Bourgeois (1996). Experimental evidence for dynamic social impact: the emergence of subcultures in electronic groups. *Journal of Communication, 46*(4), 35-47.

Li, H.L. (2004). Virtual community studies: a literature review, synthesis and research agenda. *Proceedings of the Americas conference on information systems,* 2708-2715.

Lin, C.F. (2008). The cyber-aspects of virtual communities: free downloader ethics, cognition, and perceived service quality. *Cyberpsychology & behavior, 11*(1), 69-73.

Lin, F.R. & C.M. Hsueh (2006). Knowledge map creation and maintenance for virtual communities of practice. *Information Processing & Management, 42*(2), 551-568.

Lin H.F. (2008). Determinants of successful virtual communities: contributions from system characteristics and social factors. *Information & Management, 45*(8), 522-527.

Lin, H.F. (2008). Antecedents of virtual community satisfaction and loyalty: an empirical test of competing theories. *Cyberpsychology & behavior, 11*(2), 138-144.

Lin, H.F. (2007). The role of online and offline features in sustaining virtual communities: an empirical study. *Internet Research, 17*(2), 119-138.

Lin, H.F. (2006). Understanding behavioral intention to participate in virtual communities. *Cyberpsychology & Behavior, 9*(5), 540-547.

Lin, H.F. & G.G. Lee (2006). Determinants of success for online communities: an empirical study. *Behaviour & Information Technology, 25*(6), 479-488.

Lin, W.K., C.K. Chiu & Y.H. Tsai (2008). Modeling relationship quality and consumer loyalty in virtual communities. *Cyberpsychology & Beahvior, 11*(5), 561-564.

Lu, Y., L. Zhao & B. Wang (2010). From virtual community members to C2C e-commerce buyers: trust in virtual communities and its effect on consumers' purchase intertion. *Electronic Commerce Research and Applications, 9*(4), 346-360.

Ma, M. & R. Agarwal (2007). Through a glass darkly: information technology design, identity verification, and knowledge contribution in online communities. *Information Systems Research, 18*(1), 42-67.

Mahadevan, B. (2000). Business models for Internet-based e-commerce: an anatomy. *California Management Review, 42*(4), 55-69.

Marshall, G. (2000). Virtual communities and their network support: a cybernetic analysis. *Cybernetics and Systems: An International Journal, 31*(4), 397-415.

Mathwick, C., C. Wiertz & K.D. Ruyter (2008). Social capital production in a virtual P3 community. *Journal of Consumer Research, 34*(6), 832-849.

Meyer, A.D., A.S. Tsui & C.R. Hinings (1993). Configurational approaches to organizational analysis. *Academy of Management Journal, 36*(6), 1175-1195.

Nantel, J & Y. Sekhavat (2008). The impact of SMS advertising on members of a virtual community. *Journal of Advertising Research, 48*(3), 363-374.

Pan, W. & X.Y. Lan (2009). Building a virtual community platform for subject information services at Shanghai Jiao Tong University Library. *Electronic Library, 27*(2), 271-282.

Phoenix K.H.M. & S.C. Neil (2008). Exploring the communication of social support within virtual communities: a content analysis of messages posted to an online HIV/AIDS support group. *Cyberpsychology & Behavior, 11*(3), 371-374.

Pliskin, N. & C.T. Romm, (1997). The impact of e-mail on the evolution of a virtual community during a srike. *Information & Management, 32*(5), 245-254.

Porter, C.E. & N. Donthu (2008). Cultivating trust and harvesting value in virtual communities. *Management Science, 54*(1), 113-128.

Rice, R. (1980). The impacts of computer-mediated organizational and interpersonal communication. In M. Williams (Eds.), *Annual review of Information Science and Technology*. N.Y.: Knowledge Industry Publications.

Ridings, C.M., D. Gefen & B. Arinze (2002). Some antecedents and effects of trust in virtual communities. *Journal of Strategic Information Systems, 11*(3-4), 271-295.

Romm, C., N. Pliskin & R. Clarke (1997). Virtual communities and society: toward and integrative three phase model. *International Journal of Information Management, 17*(4), 261-270.

Rothaermel, F.T. & S. Sugiyama (2001). Virtual Internet communities and commercial success: individual and community-level theory grounded in the atypical case of TimeZone.com. *Journal of Management, 27*(3), 297-312.

Rullani, F. & Haefliger, S. (2013). The periphery on stage: the intra-organizational dynamics in online communities of creation. *Research Policy, 42*(4), 941-953.

Shang, R.A., Y.C. Chen & H.J. Liao (2006). The value of participation in virtual consumer communities on brand loyalty. *Internet Research, 16*(4), 398-418.

Song, J. & Y.J. Kim (2006). Social influence process in the acceptance of a virtual community service. *Information System Front, 8*(3), 241-252.

Suh, A. (2013). The influence of self-discrepancy between the virtual and real selves in virtual communities. *Computers in Human Behavior, 29*(1), 246-256.

Sun, Y., Y. Fang & K.H. Lim (2012). Understanding sustained participation in transactional virtual communities. *Decision Support Systems, 53*(1), 12-22.

Suzor, N. (2009). On the inalienable rights of participants in virtual communities. *Media International Australia incorporating Culture and Policy, 130*, 90-101.

Tai, H.T. & P. Pai (2013). Explaining members' proactive participation in virtual communities. *International Journal of Human-Computer Studies, 71*(4), 475-491.

Teo, H.H., H.C. Chan, K.K. Wei & Z. Zhang (2003). Evaluating information accessibility and community adaptivity features for sustaining virtual learning communities. *International Journal of Human-Computer Studies, 59*(5), 671-697.

Tönnies, F. (1967). *Gemeinschaft and Gesellschaft: the sociology of community.* London, Frank Cass Co. Ltd.

Tonteri, L., et al. (2011). Antecedents of an experienced sense of virtual community. *Computers in Human Behavior, 27*(6), 2215-2223.

Valck, K.D., F. Langerak, P.C. Verhoef & W.J. Verlegh (2007). Satisfaction with virtual communities of interest: effect on members' visit frequency. *British Journal of Management, 18*(3), 241-256.

Ward, K. (1999). Cyber-ethnography and the emergence of the virtually new community. *Journal of Information Technology, 14*(1), 95-105.

Wellman, B. & M. Gulia (1999). *Communities in cyberspace: virtual communities as communities: net surfers don't ride alone.* London: Routledge.

Wessner, M. & H.R. Pfister (2001). Group formation in computer-supported collaborative learning. Presented to the 2001 International ACM SIGGROUP Conference on Supporting Group Work, Colorado, USA.

Wu, J.J., Y.H. Chen & Y.S. Chung (2010). Trust factors influencing virtual community members: a study of transaction communities. *Journal of Business Research. 63*(9-10), 1025-1032.

Wu, J. J. & A. Tsang (2008). Factors affecting members' trust belief and behaviour intention in virtual communities. *Behaviour & Information Technology, 27*(2), 115-125.

Young, M.L. & F.C. Tseng (2008). Interplay between physical and virtual settings for online interpersonal trust formation in knowledge-sharing practice. *Cyberpsychology & behavior, 11*(1), 55-64.

Yu, C.P. & M.L. Young (2008). The virtual group identification process: a virtual educational community case. *Cyberpsychology & Behavior, 11*(1), 87-90.

Zhang, Y., et al. (2010). Exploring the role of psychological safety in promoting the intention to continue sharing knowledge in virtual communities. *International Journal of Information Management. 30*(5), 425-436.

Zhao, L., et al. (2012). Cultivating the sense of belonging and motivating user participation in virtual communities: a social capital perspective. *International Journal of Information Management, 32*(6), 574-588.

EFFECT OF DIFFERENT DATABASE STRUCTURE REPRESENTATIONS, QUERY LANGUAGES, AND TASK CHARACTERISTICS ON INFORMATION RETRIEVAL

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ABSTRACT

This research paper investigates the impact of different database structure representations, query languages, and task complexity on an information retrieval task. Cognitive fit theory is used to formulate four hypotheses based on different measures of end-user performance. A laboratory experiment is conducted to test the hypotheses. Participants include students majoring in accounting and management information systems (MIS). Analysis of variance and post hoc means comparisons are used to analyze the results. While previous research manipulated only the database structure representation or the query language, this research project extends the current research in accounting and information systems by manipulating both the database structure representation and the query tool. User characteristics, such as professional skills, are explicitly included in the research model, where these previously had been ignored. The findings of the current study cannot be explained by cognitive fit theory. Different combinations of database structure representation and query language are best suited depending on the measure of performance used and on user characteristics. These results have practical implications, because they can help professionals determine the type of database documentation and query tools specific end-users need to access and use to improve their performance in query writing tasks. This study also reveals that user characteristics are important factors to be considered when investigating the end-user's performance. These characteristics should help practitioners and academics designing and implementing customized training.

INTRODUCTION

The accounting and business communities increasingly rely on database applications to convert raw data into useful business information (Hayes and Hunton, 2000). Today, a majority of accounting information systems use relational databases (Hooper and Page, 1996). In the past, information systems (IS) professionals, not end-users, were responsible for query tasks (Borthick, 1992). Recently, this function has shifted to end-users as accounting systems use more easily accessible databases (Hooper and Page, 1996). End-users (e.g., accountants, auditors, and managers) must understand the database structure and be able to use the available query language to transform accounting data into useful business information (Leitheiser and March, 1996).

Accounting end-users must be able to discern whether the potential information is available and then retrieve it (Borthick, 1992). A database structure representation communicates the availability of accounting data (Dunn and Grabski, 2002). This representation details the stored data items and their logical organization. Examples include the entity-relationship (ER) model and the relational model. Accessing data of interest requires knowledge of a database

query language. Examples include query-by-example (QBE) and structured query language (SQL).

The IS literature is unclear concerning how database representation type, query tool type, and user characteristic affect end-user performance in query construction tasks. According to Dunn and Grabski (2002, 168), "prior research has not examined these factors or their interactions in a systematic way, as this is a relatively new research field." They propose that these factors be studied further to learn more about their combined effects on query writing performance.

Past empirical research on information retrieval typically compares one representation model to another, while keeping the language constant (Lochovsky and Tsichritzis, 1977; Jih et al., 1989; Davis, 1990; Chan et al., 1993; Leitheiser and March, 1996), or compares one query language against another without regard to the database representation (Reisner et al., 1975; Chamberlin et al., 1976; Zloof, 1977; Greenblatt and Waxman, 1978; Reisner, 1981; Yen and Scamell, 1993). Only one study manipulated both the database structure representation and the query language (Chan et al., 1993). The current study manipulates both the data model and the query language. Chan et al. (1993), however, did not investigate the interaction between the two factors. The current study solves this problem by analyzing the main effects as well as the interaction of the different factors affecting end-user query performance.

Prior research on query languages, which typically holds the data model constant, suggests that a graphical tool is easier to use, but only for nonprogrammers (Reisner et al., 1975). Prior research on data models indicates overwhelming superiority of the graphical version of the data model for database designing tasks (Batra et al., 1990). Results were inconsistent for those studies that manipulated the data model while investigating user performance in query writing tasks (Jih et al., 1989; Chan et al., 1993). None of these studies examines the use of QBE as a retrieval technique. Therefore, this study includes both SQL and QBE as query languages.

Accountants, auditors, and managers use a variety of query tools, depending on their database management system. In addition, all prior experiments except Amer (1993) used IS students as participants. Therefore, this study uses accounting and MIS students as proxies for potential DBMS end-users. This is the first study that incorporates user characteristics in the research model.

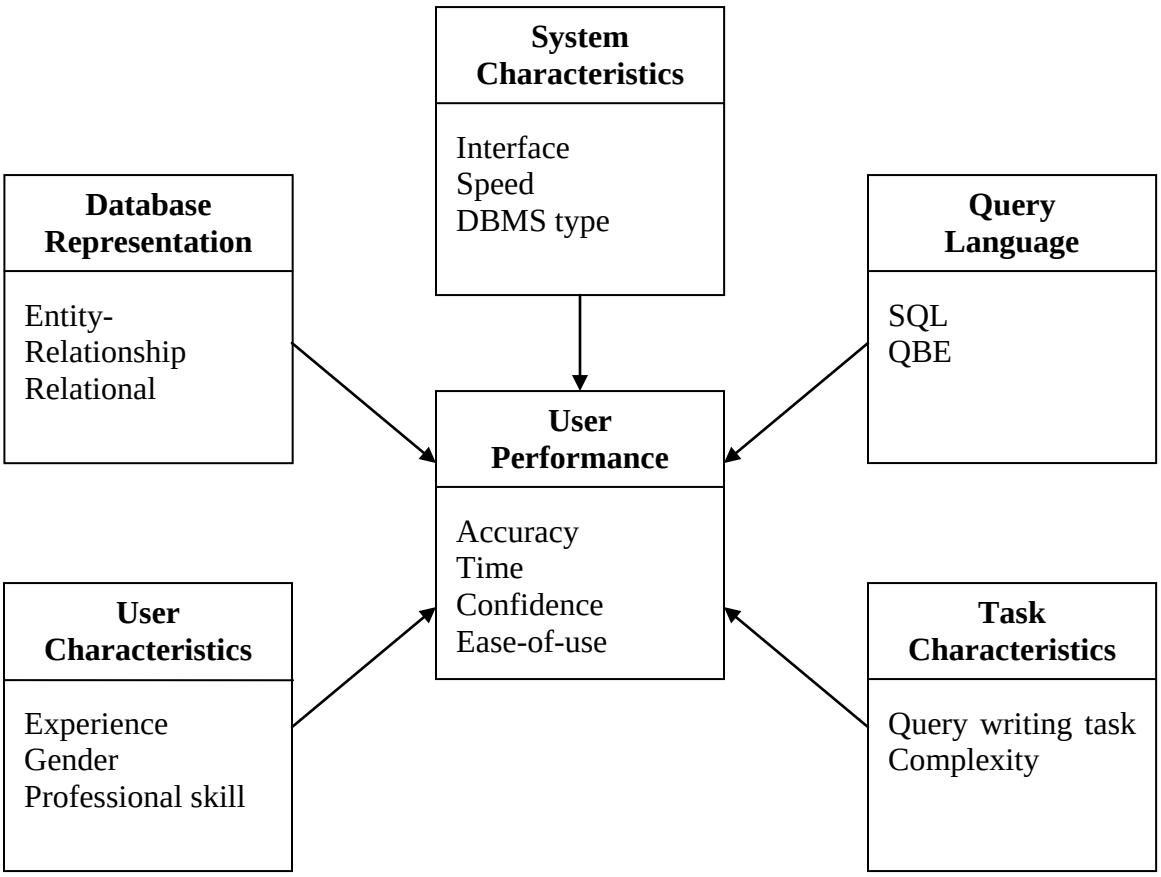
This study investigates the influence of database structure representation, query language, and task characteristics on user performance in the information retrieval process. Organizations often implement formal training programs to teach their new hires and experienced employees the skills they will need, including the ability to efficiently and effectively query a database. Training can be costly to the organization, in both lost production time and costs of the program itself (potential travel costs, instructor's fees, and materials). By implementing the concepts of this research, organizations can increase the value added from the training and also reduce the cost of the training. By better understanding how the combination of database documentation and query tools can affect the end-users performance in query writing tasks organizations will be able to implement specific trainings that improve the employee's retention and performance.

The rest of the paper is organized as follows. The next section describes the research model and formulates the hypotheses. The third section explains the research design and methodology. The fourth section reports the experiment results. The last section discusses the study results and conclusions.

HYPOTHESIS DEVELOPMENT

Figure 1 synthesizes the IS data model and query language literature and extends it to a proposed research model for the database user's performance in query writing tasks. The model indicates that the user's performance is influenced by the following five factors: database representation, query language, system characteristics, task characteristics, and user characteristics. A similar version of this research framework is suggested by Dunn and Grabski (2002) as a basis for future research in this field.

Figure 1
Research Model



The majority of the prior research manipulated ony one or two facets of this research model. In the current study, only the system characteristics (such as response time, physical input/output devices, and user interface) are controlled. Data model, query language, user characteristics, and task characteristics are manipulated and relationships between them are investigated.

Cognitive fit literature can be used to explain the relationship between the data model type and the query language type. Cognitive fit theory was originally developed by Vessey (1991) and further improved to explain previously conflicting results regarding relative performance of users presented with information in graphical versus tabular formats (Umanath and Vessey, 1994; Vessey, 1994; Vessey and Galletta, 1991).

According to the theory, when the types of information emphasized in the problem-solving elements (problem representation and task) match, the problem solver can use processes and formulate mental representations that emphasize the same type of information. Consequently, the processes the problem solver uses, both to act on the problem representation and to complete the task, will match. This superior mental representation will result in more effective problem-solving performance (Vessey 1991).

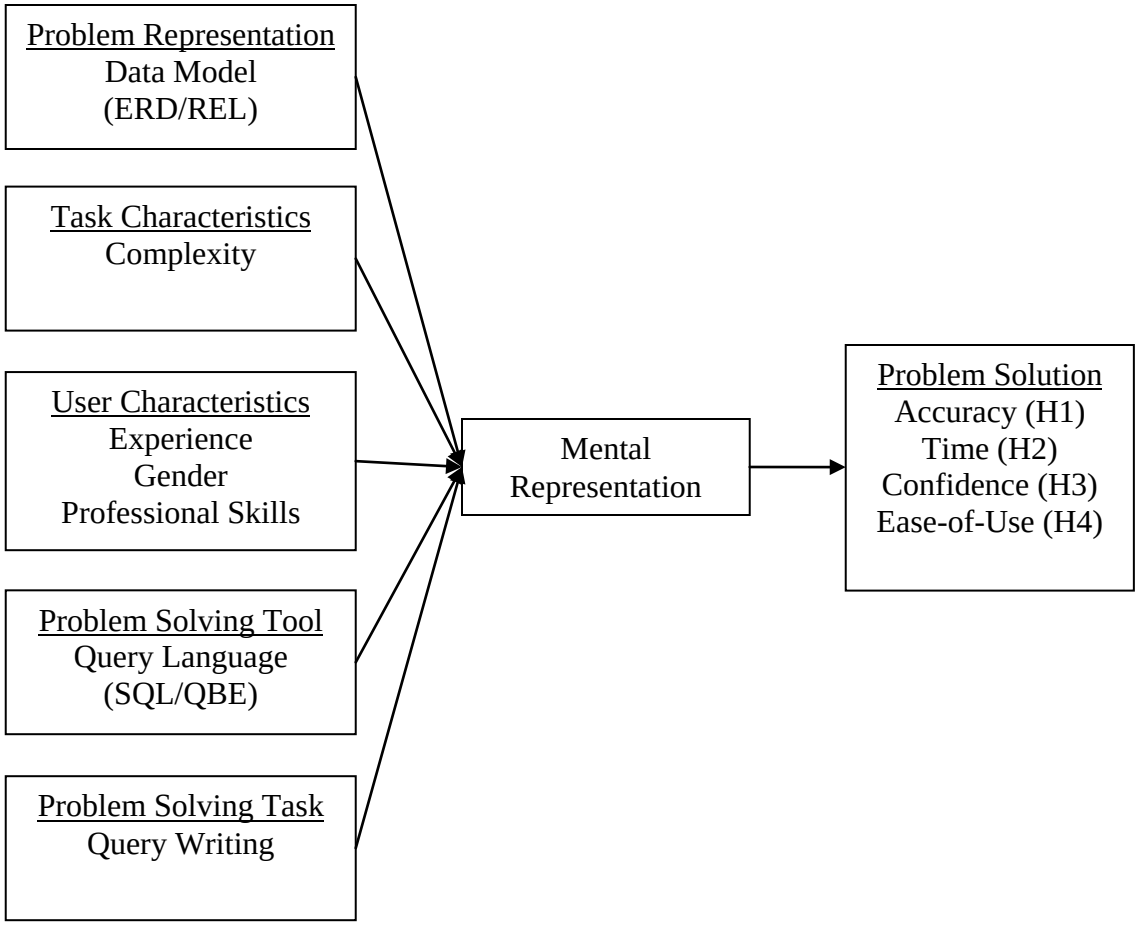
Conversely, when a mismatch occurs between problem representation and task, cognitive fit will not occur, because similar problem-solving processes cannot be used to both act on the problem representation and solve the problem. Because problem solvers form mental representations from materials presented to them, the mental representations likely will be strongly influenced by problem representations. In a mismatch situation, the users must transform their mental representation to derive a solution to the problem. Alternatively, they may formulate mental representations based on the task. In this case, they must transform the data derived from the problem representation into a mental representation suitable for the task solution. In either case, problem-solving performance will deteriorate (Sinha and Vessey, 1992).

Smelcer and Carmel (1997) and Dennis and Carte (1998) applied basic cognitive fit theory to the geographic information systems domain, using it to explain performance differences among users of map and table-based geographic information systems on geographic relationship tasks. Dunn and Grabski (2001) applied cognitive fit to accounting models and integrated cognitive fit theory with the concept of localization to provide additional evidence for how cognitive fit works. Their study compared the traditional debit-credit accounting model with the resources-events-agents (REA) accounting model (McCarthy 1982). The results indicate that task characteristics are important when determining the model representation that best supports the task.

Related research in human problem-solving has examined factors other than task and representation that could affect problem-solving performance. Sinha and Vessey (1992) extended the basic model of cognitive fit to include the problem-solving tool as an additional determinant of problem-solving performance. They argued that matching the type of information provided by the tool, the task, and the problem representation would lead to improved problem-solving performance. Vessey and Weber (1986) conducted an experiment that tested an extended notion of cognitive fit. They found support for the performance effects of matching both the problem-solving tool to the task and the problem representation to the task.

Figure 2 represents the extended cognitive fit theory (Sinha and Vessey, 1992). In this study, the problem representation is characterized by the database structure representation. The ER model has a two-dimensional syntax while the relational model displays the information using a linear syntax. The problem-solving tool in this case is the type of query language. QBE uses a two-dimensional syntax. Conversely, SQL uses a linear syntax. The problem-solving task is query writing based on a particular data model using a specific query language. The authors also add the user characteristics (experience, gender, and professional skills of the query writer) and task characteristics defined by the complexity of the queries as important elements.

Figure 2
Extended Problem Solving Model of Cognitive Fit



Based on the extended cognitive fit theory, the matching of problem representation (data model), the problem-solving tool (query language), and the problem-solving task (query writing) will result in superior user performance in information retrieval (i.e., query accuracy, time to completion, user confidence, and perceived ease-of-use). When the degree of cognitive fit between the database representation and the query language is high, participants will generate more correct queries than when the cognitive fit level is low. The following hypothesis is formulated:

H1 *ER/QBE or Relational/SQL participants will generate more correct queries than Relational/QBE or ER/SQL participants.*

Cognitive fit theory predicts that users of information that is consistent across problem and task representation will perform more quickly than users of inconsistent information, because less cognitive effort is required to process the information. When the degree of cognitive fit between the database representation and the query language is high, participants will complete the task faster than when the cognitive fit level is low. Thus, the following hypothesis is formulated:

H2 *Task completion time will be lower for the ER/QBE or Relational/SQL participants than for the Relational/QBE or ER/SQL participants.*

Dunn and Grabski (2001) were the first to investigate the effect of cognitive fit on user confidence. Their results did not support the claim that users' confidence in their responses increases with correctness. Prior research found an inverse relationship between accuracy and confidence (Dickson et al., 1977). Nevertheless, when the degree of cognitive fit between the database representation and the query language is high, participants will be more confident about their answers than when the cognitive fit level is low. The following hypothesis is formulated:

H3 *ER/QBE or Relational/SQL participants will be more confident about their answers than Relational/QBE or ER/SQL participants.*

If the problem representation, the problem-solving tool, and task do not match, the decision maker must reformulate the mental representation to match with the problem representation, the tool, and the task. Thus, the decision maker will perceive the task to be more difficult. Conversely, when the degree of cognitive fit between the database representation and the query language is high, participants will perceive that the combination is easier to use than when the cognitive fit level is low. The following hypothesis draws on these relationships:

H4 *ER/QBE or Relational/SQL participants will perceive the combination easier to use than Relational/QBE or ER/SQL participants.*

User performance is evaluated in term of query accuracy, task completion time, user confidence level, and perceived ease-of-use. The matched groups (ER/QBE and Relational/SQL) are expected to outperform the unmatched groups (ER/SQL and Relational/QBE) in each user performance measure based on the cognitive fit theory.

METHOD

A laboratory experiment using a 2x2x2 factorial design was conducted to test the research hypotheses. The general methodological design is straightforward and similar to many previous studies (e.g., Chan et al., 1993; Dunn and Grabski, 2001). Participants are undergraduate accounting and MIS students who participated in the experiment for class credit. These subjects have little, if any, prior exposure to data modeling and query writing.

Participants within both majors were randomly assigned to four groups. The first two groups received training on the ER model. The other two groups received training on the relational model. Each group was trained on the use of a particular query tool: SQL or QBE. Then, they were asked to write a series of queries using the query tool and database representation on which they have been trained. All participants received a description of the same database and one type of database representation according to their prior database structure representation training. Relational and ER documentation were based on the same database domain, and both sets of system documentation contained all information needed to complete the experimental tasks.

Experimental Protocol

The different parts of the experiment were divided into three phases: registering, training, and testing. Both training and testing phases were conducted in a computer laboratory. Participants were required to complete all parts of the experiment to receive full credit.

For the training and testing phases, a web application was designed to administer both parts of the experiment. To develop the training and testing materials, standard database management textbooks were consulted (e.g., McFadden et al., 1999; Pratt, 2001; Pratt and Adamski, 2002). In addition, expert faculty reviewed the experimental materials and their recommendations were reflected in the final draft of the experiment.

Participants completed the training and testing phases during two different sessions separated by a week. During the training phase, participants were given general instructions on how to complete this phase. Then, the students completed a demographic questionnaire. In addition to age, gender, and major, level of experience with databases and query languages was evaluated. A similar demographic questionnaire was used in prior studies (e.g., Leitheiser and March, 1996).

In the first part of the training, participants received instruction on understanding a database structure representation, either ER or relational. The database structure representation training included a description of important concepts in relational databases, such as primary keys and foreign keys. Also, it describes characteristics of one particular database structure representation. At the end of this training, participants were asked a series of multiple-choice questions to measure their understanding of database structure concepts. Participants received explanatory feedback on each of their answers.

After completing the database structure representation training, participants received training on a database query technique (QBE or SQL). To maintain consistency, the same domain (purchasing cycle) was used in the query language training. Topics used in the query language training include: simple retrieval, conditional selection, compound conditions, aggregate functions, sorting, grouping, and joining tables. These topics represent the major parts of select queries. For each of these topics, participants were presented with a sample query used to illustrate the concepts. The QBE grid is adapted from the one used by a popular database software program (Microsoft® Access).

At the end of each query topic, participants were able to practice their procedural knowledge of the query tool and received explanatory feedback in the form of the correct answer and explanations for it. Practice with explanatory feedback has been shown to increase procedural knowledge (Bonner and Walker, 1994). At the end of the query language training, participants received a summary of the database structure representation characteristics and the query language syntax and procedures.

Microsoft® Word was used to calculate readability scores for the content of the training. The Flesch Reading Ease score (Flesch 1948) rates the text on a 100-point scale. A higher score indicates a more understandable document. The Flesch Reading Ease score (Kincaid and McDaniel, 1974) for the training was 51. The Flesch-Kincaid Grade Level score rates the text on a U.S. grade school level. The training received a score of 9.3. This indicates that a ninth grader can understand the document. These scores are appropriate for upper-level undergraduate college students.

In the testing phase of the experiment, the students were asked to construct eight queries based on a new database domain (customers and parts). This test consists of four parts. In the first part, the participants reviewed the training material using a review sheet. The participants

were told that they could view this page anytime during the test. In the second part, the participants received a description of a database structure used by a company to store its sales order transactions. Along with the description, the participants had access to the database structure representation they have been trained to understand (ER or relational).

In the third part of the testing phase, the participants were asked to provide their answers to eight different queries using the query language with which they had been trained (QBE or SQL). After each query, the students indicated their confidence level regarding their answer and their opinion about the query complexity. The order of the queries was randomized to avoid any order effect. The last part of the experiment consists of a questionnaire measuring the perceived ease-of-use. A week after the testing phase, all participants received a debriefing on the experiment and the correct answer for each query.

Independent Variables

Query language and *data model* are the between-subjects independent variables manipulated in this study. *Query complexity* is the within-subjects independent variable. Each participant completed eight queries. The queries are classified as simple or complex. *Query complexity* is based on the measurement scheme proposed by Reisner (1981) and the ranking of subject matter experts. A query is classified as simple if it requires the use of simple mapping (one table), simple selection, and/or simple condition. After completing each query question, the participants were asked to indicate their opinion about the level of complexity of the query they just finished to answer. The query complexity level is measured using a 7-point Likert scale question where 1 is very simple and 7 very complex. The complexity data is used as a manipulation check. Four queries were classified as simple because those queries only require one table and simple condition to obtain the information. Also, expert faculty in databases ranked those queries as simple. Every participant ranked those as simple. The other four queries are classified as complex because they require two or more tables, compound criteria, and an expression builder to provide the information. Every participant ranked those as the most complex.

In addition, the means for simple queries and complex queries were compared for both accounting and MIS participants. The difference between simple and complex queries across manipulation groups is significant ($p<0.001$). The accounting and MIS groups agree on the level of complexity for the complex queries ($F = 2.42$, $p = 0.123$). However, their opinions differ about the level of complexity for the simple queries ($F = 25.41$, $p<0.000$). The difference in complexity rating between simple and complex queries for the MIS groups is more defined than for the accounting groups. This finding should not have any impact on the hypotheses testing results because complexity is the within-subject manipulation and both majors displayed a clear cut between the two sets of queries, thus providing evidence for successful manipulation. Age, gender, major, and experience are included as covariates.

Dependent Variables

The dependent variables measured in this study are *query accuracy*, *query task completion time*, *user confidence*, and *perceived ease of use*. To measure *query accuracy*, query solutions were developed, and a specific grading protocol was agreed upon and applied by two independent graders.

The graders scored all participants' solutions for one query and then moved on to the next query. Possible total scores for each query vary because of the different complexity levels, as well as the number of fields, tables, criteria, and links associated with each query. In studies using more than one rater, measuring inter-rater agreement is important. The Kappa statistic was used to evaluate the extent of agreement between raters (Cohen, 1960). Individual query Kappa statistics were above 0.8 and the overall Kappa statistic is 0.91 which reflects almost perfect agreement between the two raters (p=<0.0001). The *query task completion time* is measured as the number of seconds participants spent completing each of the eight queries.

User confidence is measured separately for each query task using an 11-point scale anchored at 0% (extremely unconfident) and 100% (extremely confident). *Perceived ease of use* is measured after the participants have completed all of the query tasks. *Perceived ease of use* is measured using five 7-point Likert scale questions adapted from Davis (1989). The original instrument and adaptations have been used in prior studies with high reported reliability (Cronbach's alpha has ranged from 0.83 in Batra et al. [1990] to 0.93 in Amer [1993]). Cronbach's coefficient alpha (Cronbach, 1951) was computed to assess the level of internal consistency reliability for the perceived ease-of-use construct. The result (0.84) is comparable to the Cronbach's coefficient alpha reported in prior studies.

RESULTS

One hundred sixty-one undergraduate students majoring in accounting (78) and MIS (44) participated in the experiment for class credit. Accounting students were registered in their first introductory AIS course. MIS students were registered in their first introductory database course. Those students had not yet been exposed to any database concepts. After completion of the experiment, data for 123 participants were usable for analysis. The reduction in the number of participants is attributable to technical problems when implementing the experimental materials and to some participants who did not fully complete the experiment nor provide answers to every question.

Demographic Statistics

Demographic data of the accounting participants for the four different groups (ER/SQL, ER/QBE, Relational/SQL, and Relational/QBE) are reported in table 1. The number of participants in the four groups is similar ($\chi^2 = 0.84$, $p = 0.358$). No differences in gender are found among the four groups ($\chi^2 = 1.28$, $p = 0.733$). In each of the four groups, female participants form the majority. Concerning age, data for a 47 year-old participant were deleted from the sample because of their large effect. After the elimination, no significant differences in age are found among the treatment groups ($F = 3.02$, $p = 0.087$). The means range between 20 and 22 years of age. No significant differences among groups exist based on the number of courses taken prior to the experiment that deal with productivity software, programming languages, databases design, and databases software. The most experience that accounting participants received prior to the experiment is in the number of courses with productivity software as the main topic (one or two courses).

Table 1
Participant Demographic Statistics

Accounting		ER/SQL	ER/QBE	Rel/SQL	Rel/QBE	Test statistic	p-value
Number of participants		22	16	19	21	0.84†	0.358
Gender:	Male	10	6	7	11	1.28†	0.733
	[Female]	[12]	[10]	[12]	[10]		
Age:	Mean	20.5	20.87*	21.7	20.5	3.02‡	0.087
	(StDev)	(1.79)	(1.13)	(3.04)	(1.25)		
	[Median]	[20]	[21]	[21]	[20]		
Course #1[a]:	Mean	1.4	1.5	1.6	1.6	0.24‡	0.624
	(StDev)	(0.66)	(0.97)	(0.83)	(1.03)		
	[Median]	[1]	[1.5]	[2]	[2]		
Course #2[b]:	Mean	0.5	0.5	0.2	0.3	0.16‡	0.693
	(StDev)	(0.86)	(0.73)	(0.42)	(0.56)		
	[Median]	[0]	[0]	[0]	[0]		
Course #3[c]:	Mean	0.3	0.4	0.3	0.4	0.02‡	0.894
	(StDev)	(0.55)	(0.72)	(0.58)	(0.59)		
	[Median]	[0]	[0]	[0]	[0]		
Course #4[d]:	Mean	0.0	0.2	0.0	0.1	2.05‡	0.156
	(StDev)	(0.00)	(0.408)	(0.00)	(0.22)		
	[Median]	[0]	[0]	[0]	[0]		
MIS		ER/SQL	ER/QBE	Rel/SQL	Rel/QBE	Test statistic	p-value
Number of participants		12	7	14	11	0.23†	0.632
Gender:	Male	8	5	12	7	1.88†	0.598
	[Female]	[4]	[2]	[2]	[4]		
Age:	Mean	20.3	20.7	22.0	21.2	0.43‡	0.518
	(StDev)	(1.56)	(1.50)	(4.49)	(2.14)		
	[Median]	[20]	[20]	[20]	[20]		
Course #1[a]:	Mean	1.1	1.0	1.3	0.9	0.31‡	0.582
	(StDev)	(0.79)	(0.82)	(0.73)	(1.04)		
	[Median]	[1]	[1]	[1]	[1]		
Course #2[b]:	Mean	2.9	2.3	2.6	3	2.91‡	0.096
	(StDev)	(0.90)	(0.76)	(1.22)	(0.89)		
	[Median]	[3]	[2]	[3]	[3]		
Course #3[c]:	Mean	0.1	0.3	0.1	0.4	0.00‡	0.950
	(StDev)	(0.29)	(0.49)	(0.36)	(0.67)		
	[Median]	[0]	[0]	[0]	[0]		
Course #4[d]:	Mean	0.0	0.1	0.1	0.1	1.12‡	0.296
	(StDev)	(0.00)	(0.38)	(0.36)	(0.30)		
	[Median]	[0]	[0]	[0]	[0]		

[a] Number of courses - main topic: productivity software
[b] Number of courses - main topic: programming languages
[c] Number of courses - main topic: databases design
[d] Number of courses - main topic: databases software
† χ^2-statistic
‡ F-statistic
* One observation with a value of 47 for age was deleted from the sample because of large effect on the sample. Including this data will change the mean (standard deviation) to 22.5 (6.62) and change F (p-value) to 3.96 (0.05)

Table 1 also presents the demographic data for the four MIS groups. Nonparametric tests, to evaluate the equal sample sizes among the four groups, resulted in no significant differences in terms of number of participants (χ^2 = 0.23, p = 0.632). No significant differences were found among the four groups based on gender, age, and prior educational experiences.

In contrast to the accounting participants, more MIS participants are males. MIS students have more programming background ($median_{course\#2,\ MIS}$ = 3, $median_{course\#2,\ Acc}$ = 0). This finding should impact participant performance in completing the query task. MIS groups who used SQL as a query tool may be more comfortable typing the SQL code than using the mouse. These differences in educational experience and gender between the accounting and MIS participants are the reason for separating the two groups when investigating the results.

Results of Hypothesis Testing

The hypotheses and the research question were analyzed using a repeated measures general linear model. The factors data model and query language are crossed factors while complexity is a repeated measures factor. User characteristics defined by age, gender, experience are included in the model as covariates. Experience is the total number of courses with productivity software, programming languages, database design and software as topics. Query accuracy, task completion time, user confidence, and perceived ease-of-use were each analyzed separately.

Statistical analysis was computed first by including both accounting and MIS participants as part of the sample. Major was one of the covariates and was significant for query accuracy, user confidence, and perceived ease-of-use (p = 0.003, p = 0.001, p<0.001, respectively). General linear model was computed to see the existence of a three-way interaction among data model, query language, and major. Only the three-way interaction is significant for perceived ease-of-use (F = 5.88, p = 0.017). The following subsections present the results for each type of participant treated separately.

Following the ANOVA for each dependent variable, the hypotheses were tested by contrasting combinations of treatments that have similar characteristics. Matched groups' means (ER/QBE and Relational/SQL) were combined and compared with unmatched groups' means combination (ER/SQL and Relational/QBE). The post hoc tests include t-tests on the difference between the two pairs of contrast groups' means. Results of Tukey HSD pairwise contrasts are reported.

H1: Query Accuracy

Hypothesis 1 (H1) states that ER/QBE and Relational/SQL participants will generate more correct queries than Relational/QBE and ER/SQL participants. Table 2, panel A presents ANOVA results with query accuracy as the dependent variable for the accounting participants and the MIS participants.

Table 2
Analysis of Variance

Panel A – Query Accuracy as Dependent Variable

		Task Complexity							
		Simple Queries				*Complex Queries*			
Source	*d.f.*	*F*-Statistic		*p*-value		*F*-Statistic		*p*-value	
Independent Variables:		Acc	MIS	Acc	MIS	Acc	MIS	Acc	MIS
Data Model	1	0.08	1.69	0.78	0.20	1.57	1.54	0.21	0.22
Query Language	1	2.60	3.62	0.11	0.07*	1.10	5.05	0.30	0.03**
Data Model x Query Language	1	0.13	5.63	0.72	0.02**	1.22	3.90	0.27	0.06*
Covariates:									
Age	1	0.69	0.83	0.41	0.37	0.83	0.61	0.37	0.44
Gender	1	2.70	1.38	0.11	0.25	2.90	3.95	0.09*	0.05*
Experience	1	0.42	0.18	0.52	0.68	2.74	1.25	0.10*	0.27

Panel B – Time Completion as Dependent Variable

		Task Complexity							
		Simple Queries				*Complex Queries*			
Source	*d.f*	*F*-Statistic		*p*-value		*F*-Statistic		*p*-value	
Independent Variables:		Acc	MIS	Acc	MIS	Acc	MIS	Acc	MIS
Data Model	1	0.00	0.59	0.97	0.45	0.04	0.56	0.83	0.46
Query Language	1	15.02	27.29	0.00**	0.00**	5.86	11.94	0.02**	0.00**
Data Model x Query Language	1	0.00	8.68	0.97	0.01**	0.97	0.52	0.33	0.47
Covariates:									
Age	1	7.51	0.64	0.01**	0.43	1.62	1.06	0.21	0.31
Gender	1	1.98	0.17	0.16	0.69	0.87	1.09	0.36	0.30
Experience	1	0.41	1.95	0.52	0.17	0.55	0.28	0.83	0.60

Panel C – User Confidence as Dependent Variable

		Task Complexity							
		Simple Queries				*Complex Queries*			
Source	*d.f.*	*F*-Statistic		*p*-value		*F*-Statistic		*p*-value	
Independent Variables:		Acc	MIS	Acc	MIS	Acc	MIS	Acc	MIS
Data Model	1	2.25	0.02	0.14	0.90	1.06	1.29	0.31	0.26
Query Language	1	0.78	0.19	0.38	0.67	3.45	3.05	0.07*	0.09*
Data Model x Query Language	1	0.04	4.45	0.84	0.04**	0.98	1.82	0.33	0.19
Covariates:									
Age	1	0.19	0.37	0.66	0.55	0.62	0.61	0.43	0.44
Gender	1	1.10	0.00	0.30	0.95	0.68	0.45	0.41	0.51
Experience	1	3.00	1.09	0.09*	0.30	0.81	0.55	0.37	0.46

Panel D – Perceived Ease-of-Use as Dependent Variable

Source	*d.f.*	*F*-Statistic		*p*-value	
Independent Variables:		Acc	MIS	Acc	MIS
Data Model	1	0.70	1.08	0.41	0.31
Query Language	1	0.17	0.09	0.69	0.76
Data Model x Query Language	1	2.12	13.03	0.15	0.00**
Covariates:					
Age	1	3.19	0.15	0.09*	0.70
Gender	1	8.26	0.24	0.01**	0.63
Experience	1	4.74	0.77	0.03**	0.39

* Significant at 0.10 level.
** Significant at 0.05 level.

For the accounting participants, no interaction or main effects for data model and query language were found (F = 0.13, p = 0.72). Gender and experience have a marginally significant impact on the complex query accuracy performance (F = 2.90, p = 0.09; F = 2.74, p = 0.10, respectively). For the MIS participants, the data model and query language interaction effect was significant (F = 5.63, p = 0.02 for simple queries; and F = 3.90, p = 0.06 for complex queries).

Only gender was significant at the 0.055 level when MIS participants completed complex queries.

Table 3 reports on contrasts mean comparison of query accuracy scores for the accounting participants. Panel A shows no significant differences for simple queries between the matched groups and the unmatched groups (t = -0.6, p = 0.551). H1 is not supported for the accounting participants. Pairwise mean comparisons show no significant differences between the four groups. Panel B shows similar results for complex queries.

Table 3
Accounting Participants Means Comparison of Query Accuracy Scores[a]

Panel A: Complexity Level – Simple Queries - Planned Contrast Test Results

Contrast	Means Difference	Standard Error	t	*df*	Prob.
$H_1 : \mu_{ER/QBE} + \mu_{Rel/SQL} > \mu_{ER/SQL} + \mu_{Rel/QBE}$	-4.87	8.12	-0.6	74	0.551

Test Statistics and Results of Tukey HSD Contrasts (results sorted in descending order by mean)

Group	Statistics mean (StDev)	Group			
		ER/SQL	Rel/SQL	Rel/QBE	ER/QBE
ER/SQL	86.49 (17.64)	-	0.553	1.476	1.676
Rel/SQL	83.41 (19.00)		-	0.875	1.113
Rel/QBE	78.48 (14.81)			-	0.303
ER/QBE	76.69 (20.02)				-

Panel B: Complexity Level – Complex Queries - Planned Contrast Test Results

Contrast	Means Difference	Standard Error	t	*df*	Prob.
$H_1 : \mu_{ER/QBE} + \mu_{Rel/SQL} > \mu_{ER/SQL} + \mu_{Rel/QBE}$	6.55	7.04	0.93	74	0.355

Test Statistics and Results of Tukey HSD Contrasts (results sorted in descending order by mean)

Group	Statistics mean (StDev)	Group			
		ER/QBE	ER/SQL	Rel/QBE	Rel/SQL
ER/QBE	57.38 (16.65)	-	1.303	1.463	1.440
ER/SQL	50.78 (17.84)		-	0.188	0.193
Rel/QBE	49.89 (11.58)			-	0.010*
Rel/SQL	49.85 (15.05)				-

[a] Accuracy scores are the average score of the individual queries converted as a percentage.
* The mean difference is significant at the 0.05 level.

Table 4 presents the mean comparison results for the MIS participants. ER/SQL and Relational/QBE groups significantly outperformed the matched group for simple queries and

complex queries (t = 2.73, p = 0.01; and t = 2.43, p = 0.02, respectively). ER/SQL group had the highest score for the simple queries and Relational/QBE group for more complex queries. H1 is not supported.

Table 4
MIS Participants Means Comparison of Query Accuracy Scores[a]

Panel A: Complexity Level – Simple Queries - Planned Contrast Test Results

Contrast	Means Difference	Standard Error	t	*df*	Prob.
$H_1 : \mu_{ER/QBE} + \mu_{Rel/SQL} > \mu_{ER/SQL} + \mu_{Rel/QBE}$	-16.34	6.01	2.73	39	0.010*

Test Statistics and Results of Tukey HSD Contrasts (results sorted in descending order by mean)

Group	Statistics mean (StDev)	Group			
		ER/SQL	Rel/QBE	Rel/SQL	ER/QBE
ER/SQL	96.53 (5.21)	-	0.212	0.930	3.034*
Rel/QBE	95.67 (8.57)		-	0.665	2.744*
Rel/SQL	93.05 (7.38)			-	2.327
ER/QBE	82.78 (17.67)				-

Panel B: Complexity Level – Complex Queries - Planned Contrast Test Results

Contrast	Means Difference	Standard Error	t	*df*	Prob.
$H_1 : \mu_{ER/QBE} + \mu_{Rel/SQL} > \mu_{ER/SQL} + \mu_{Rel/QBE}$	-21.40	8.79	2.43	39	0.020*

Test Statistics and Results of Tukey HSD Contrasts (results sorted in descending order by mean)

Group	Statistics mean (StDev)	Group			
		Rel/QBE	ER/SQL	ER/QBE	Rel/SQL
Rel/QBE	75.00 (14.66)	-	2.851*	2.491	3.690*
ER/SQL	57.99 (11.56)		-	0.015	0.780
ER/QBE	57.89 (17.27)			-	0.648
Rel/SQL	53.71 (13.53)				-

[a] Accuracy scores are the average score of the individual queries converted as a percentage.
* The mean difference is significant at the 0.05 level.

H2: Task Completion Time

Hypothesis 2 (H2) states that task completion time will be lower for the ER/QBE and the Relational/SQL groups than for the Relational/QBE and ER/SQL groups. Query task completion time ANOVA is reported in table 3, panel B for accounting participants and MIS participants.

For the accounting participants, no interaction effect was found. A main effect of query language was observed for both levels of query complexity ($F = 15.02$, $p < 0.001$; and $F = 5.86$, $p = 0.02$, respectively). Age was significant for simple queries ($F = 7.51$, $p = 0.01$).

Table 5 reports on task completion time mean comparison for the accounting participants. Both QBE groups took less time to complete the set of queries than the SQL groups. The difference between the Relational/QBE group and the other two SQL groups is significant for simple queries. The difference between Relational/QBE and Relational/SQL groups is significant for complex queries.

Table 5
Accounting Participants Means Comparison of Query Task Completion Time[a]

Panel A: Complexity Level – Simple Queries - Planned Contrast Test Results

Contrast	Means Difference	Standard Error	t	*df*	Prob.
$H_2 : \mu_{ER/QBE} + \mu_{Rel/SQL} > \mu_{ER/SQL} + \mu_{Rel/QBE}$	0:56	1:18	0.72	74	0.473

Test Statistics and Results of Tukey HSD Contrasts (results sorted in ascending order by mean)

Group	Statistics mean (StDev)	Group			
		Rel/QBE	ER/QBE	ER/SQL	Rel/SQL
Rel/QBE	05:17 (1:56)	-	-0.345	-2.954*	-3.524*
ER/QBE	05:36 (4:05)		-	-2.395	-2.951*
ER/SQL	07:50 (2:17)			-	-0.685
Rel/SQL	08:27 (3:00)				-

Panel B: Complexity Level – Complex Queries - Planned Contrast Test Results

Contrast	Means Difference	Standard Error	t	*df*	Prob.
$H_2 : \mu_{ER/QBE} + \mu_{Rel/SQL} > \mu_{ER/SQL} + \mu_{Rel/QBE}$	2:36	2:04	1.26	74	0.212

Test Statistics and Results of Tukey HSD Contrasts (results sorted in ascending order by mean)

Group	Statistics mean (StDev)	Group			
		Rel/QBE	ER/QBE	ER/SQL	Rel/SQL
Rel/QBE	09:17 (5:01)	-	-0.552	-1.723	-2.896*
ER/QBE	10:07 (4:11)		-	-1.043	-2.162
ER/SQL	11:40 (3:50)			-	-1.249
Rel/SQL	13:26 (4:58)				-

[a] All times are reported in minutes and seconds.
* The mean difference is significant at the 0.05 level.

Table 6 presents similar results for the MIS participants in term of completion time means. Both QBE groups outperformed in term of efficiency the other two SQL groups. The difference between the two QBE groups is not significant for both levels of complexity. H2 is not supported for both majors.

Table 6
MIS Participants Means Comparison of Query Task Completion Time[a]

Panel A: Complexity Level – Simple Queries - Planned Contrast Test Results

Contrast	Means Difference	Standard Error	t	*df*	Prob.
$H_2 : \mu_{ER/QBE} + \mu_{Rel/SQL} > \mu_{ER/SQL} + \mu_{Rel/QBE}$	3:18	1:08	2.93	39	0.006*

Test Statistics and Results of Tukey HSD Contrasts (results sorted in ascending order by mean)

Group	Statistics mean (StDev)	Group			
		Rel/QBE	ER/QBE	ER/SQL	Rel/SQL
Rel/QBE	3:52 (0:56)	-	-1.514	-3.235*	-6.012*
ER/QBE	5:12 (2:23)		-	-1.344	-3.766*
ER/SQL	6:20 (1:16)			-	-2.807*
Rel/SQL	8:18 (2:14)				-

Panel B: Complexity Level – Complex Queries - Planned Contrast Test Results

Contrast	Means Difference	Standard Error	t	*df*	Prob.
$H_2 : \mu_{ER/QBE} + \mu_{Rel/SQL} > \mu_{ER/SQL} + \mu_{Rel/QBE}$	1:13	2:23	0.51	39	0.616

Test Statistics and Results of Tukey HSD Contrasts (results sorted in ascending order by mean)

Group	Statistics mean (StDev)	Group			
		ER/QBE	Rel/QBE	ER/SQL	Rel/SQL
ER/QBE	09:02 (5:08)	-	-0.396	-1.803	-2.963*
Rel/QBE	09:46 (3:01)		-	-1.546	-2.841*
ER/SQL	12:17 (2:32)			-	-1.308
Rel/SQL	14:14 (4:22)				-

[a] All times are reported in minutes and seconds.
* The mean difference is significant at the 0.05 level.

H3: User Confidence

Hypothesis 3 (H3) states that ER/QBE and Relational/SQL participants will be more confident about their answers than Relational/QBE and ER/SQL participants. Results for the user confidence are similar to those of query accuracy. Those two variables are correlated ($p<0.001$,

see table 7 for accounting groups and table 8 for MIS participants). Table 2, panel C reports the ANOVA with user confidence as the dependent variable for both types of participants.

Table 7
Accounting Participants Pairwise Correlation Matrix –
Dependent Variables, Independent Variables, and Covariates

	Age	Gender	Experience	Model	Language	Score_S	Score_C	Time_S	Time_C	Conf_S	Conf_C
Gender	0.026										
	0.822										
Experience	0.136	-0.007									
	0.236	*0.952*									
Model	-0.041	-0.029	-0.038								
	0.720	*0.800*	*0.742*								
Language	0.043	-0.045	0.076	0.104							
	0.710	*0.695*	*0.509*	*0.365*							
Score_S	-0.25	0.176	0.022	-0.043	-0.207						
	*0.027**	*0.123*	*0.847*	*0.706*	*0.069*						
Score_C	-0.167	0.194	0.17	-0.12	0.091	0.692					
	0.143	*0.089*	*0.137*	*0.294*	*0.429*	*0.000**					
Time_S	0.124	0.129	0.045	-0.018	-0.437	0.213	0.105				
	0.280	*0.259*	*0.698*	*0.873*	*0.000**	*0.061*	*0.361*				
Time_C	-0.008	0.099	0.055	0.026	-0.303	0.43	0.411	0.732			
	0.945	*0.386*	*0.635*	*0.821*	*0.007**	*0.000**	*0.000**	*0.000**			
Conf_S	-0.072	0.114	0.197	-0.17	0.089	0.493	0.406	0.003	0.197		
	0.529	*0.322*	*0.084*	*0.137*	*0.440*	*0.000**	*0.000**	*0.977*	*0.084*		
Conf_C	0.07	0.067	0.127	-0.103	0.204	0.204	0.291	0.123	0.167	0.712	
	0.543	*0.561*	*0.268*	*0.370*	*0.073*	*0.073*	*0.010**	*0.285*	*0.144*	*0.000**	
Ease	0.068	0.272	0.232	-0.096	-0.073	0.234	0.261	0.254	0.225	0.427	0.529
	0.553	*0.016**	*0.041**	*0.403*	*0.524*	*0.039**	*0.021**	*0.025**	*0.048**	*0.000**	*0.000**

Pearson product-moment correlations are reported with P-value in italic.
Variable definition: Model: data model; Language: query language; Score_S: query accuracy score (simple queries); Score_C: query accuracy score (complex queries); Time_S: query task completion time (simple queries); Time_C: query task completion time (complex queries); Conf_S: user confidence level (simple queries); Conf_C: user confidence level (complex queries); Ease: perceived ease-of-use.
* Significant at 0.05 level.

For the accounting participants, the results do not show any interaction and main effects for simple tasks. Only experience is marginally significant at the 0.1 level. For the MIS participants, the data model and query language interaction effect was found to be significant for simple queries ($F = 4.45$, $p = 0.04$). None of the user characteristics was found to have an effect on the user confidence for writing simple queries. For complex queries, a main effect of query language was observed for both accounting and MIS participants ($F = 3.45$, $p = 0.07$; $F = 3.05$, $p = 0.09$, respectively).

Table 8
MIS Participants Pairwise Correlation Matrix –
Dependent Variables, Independent Variables, and Covariates

	Age	Gender	Experience	Model	Language	Score_S	Score_C	Time_S	Time_C	Conf_S	Conf_C
Gender	-0.071										
	0.650										
Experience	0.591	-0.013									
	*0.000**	*0.933*									
Model	0.156	-0.073	0.097								
	0.319	*0.643*	*0.534*								
Language	0.098	0.103	-0.003	0.091							
	0.532	*0.512*	*0.986*	*0.564*							
Score_S	-0.368	0.188	-0.364	-0.025	-0.265						
	*0.015**	*0.226*	*0.016**	*0.875*	*0.085*						
Score_C	-0.212	0.339	-0.108	0.070	0.259	0.639					
	0.172	*0.026**	*0.491*	*0.655*	*0.093*	*0.000**					
Time_S	-0.116	-0.164	-0.212	0.077	-0.626	0.175	-0.257				
	0.458	*0.294*	*0.172*	*0.624*	*0.000**	*0.261*	*0.097*				
Time_C	0.078	0.062	-0.020	0.085	-0.472	0.402	0.141	0.602			
	0.617	*0.692*	*0.900*	*0.586*	*0.001**	*0.007**	*0.366*	*0.000**			
Conf_S	-0.067	0.038	-0.113	-0.092	-0.019	0.606	0.582	-0.210	0.350		
	0.668	*0.810*	*0.469*	*0.556*	*0.905*	*0.000**	*0.000**	*0.176*	*0.021**		
Conf_C	-0.141	-0.021	-0.168	-0.202	0.255	0.353	0.521	-0.362	-0.153	0.614	
	0.369	*0.892*	*0.281*	*0.194*	*0.099*	*0.020**	*0.000**	*0.017**	*0.327*	*0.000**	
Ease	-0.042	0.160	0.169	-0.232	0.032	0.406	0.494	-0.305	0.113	0.522	0.468
	0.788	*0.307*	*0.278*	*0.134*	*0.840*	*0.007**	*0.001**	*0.046**	*0.469*	*0.000**	*0.002**

Pearson product-moment correlations are reported with P-value in italic.
Variable definition: Model: data model; Language: query language; Score_S: query accuracy score (simple queries); Score_C: query accuracy score (complex queries); Time_S: query task completion time (simple queries); Time_C: query task completion time (complex queries); Conf_S: user confidence level (simple queries); Conf_C: user confidence level (complex queries); Ease: perceived ease-of-use.
* Significant at 0.05 level.

Table 9 compares means for the accounting groups. No significant differences were found regardless of the level of query complexity. Table 10 reports the results for the MIS participants. For simple queries, a significant difference exists between the matched group and the unmatched group but in the opposite hypothesized direction ($t = -2.95$, $p = 0.005$). No significant difference was observed for complex queries. H3 is not supported for both types of participants.

Table 9
Accounting Participants Means Comparison of User Confidence[a]

Panel A: Complexity Level – Simple Queries - Planned Contrast Test Results

Contrast	Means Difference	Standard Error	t	*df*	Prob.
$H_3 : \mu_{ER/QBE} + \mu_{Rel/SQL} > \mu_{ER/SQL} + \mu_{Rel/QBE}$	-2.1	9.722	-0.22	74	0.830

Test Statistics and Results of Tukey HSD Contrasts (results sorted in descending order by mean)

Group	Statistics mean (StDev)	Group			
		ER/QBE	ER/SQL	Rel/QBE	Rel/SQL
ER/QBE	58.59 (18.17)	-	0.497	0.929	1.681
ER/SQL	55.11 (23.70)		-	0.475	1.299
Rel/QBE	52.02 (17.11)			-	0.827
Rel/SQL	46.45 (24.71)				-

Panel B: Complexity Level – Complex Queries - Planned Contrast Test Results

Contrast	Means Difference	Standard Error	t	*df*	Prob.
$H_3 : \mu_{ER/QBE} + \mu_{Rel/SQL} > \mu_{ER/SQL} + \mu_{Rel/QBE}$	-5.99	8.303	-0.72	74	0.473

Test Statistics and Results of Tukey HSD Contrasts (results sorted in descending order by mean)

Group	Statistics mean (StDev)	Group			
		ER/QBE	Rel/QBE	ER/SQL	Rel/SQL
ER/QBE	42.03 (14.67)	-	0.238	0.815	1.991
Rel/QBE	40.60 (14.94)		-	0.620	1.885
ER/SQL	37.16 (22.20)			-	1.302
Rel/SQL	29.74 (18.95)				-

[a] Confidence is measured in a scale anchored at 0% (extremely unconfident) and 100% (extremely confident).
[*] The mean difference is significant at the 0.05 level.

Table 10
MIS Participants Means Comparison of User Confidence[a]

Panel A: Complexity Level – Simple Queries - Planned Contrast Test Results

Contrast	Means Difference	Standard Error	t	*df*	Prob.
$H_3 : \mu_{ER/QBE} + \mu_{Rel/SQL} > \mu_{ER/SQL} + \mu_{Rel/QBE}$	-26.20	8.88	-2.95	39	0.005*

Test Statistics and Results of Tukey HSD Contrasts (results sorted in descending order by mean)

Group	Statistics mean (StDev)	Group			
		Rel/QBE	ER/SQL	Rel/SQL	ER/QBE
Rel/QBE	84.00 (13.03)	-	0.387	2.310	2.172
ER/SQL	81.67 (8.00)		-	2.009	1.902
Rel/SQL	70.54 (16.24)			-	0.247
ER/QBE	68.93 (18.59)				-

Panel B: Complexity Level – Complex Queries - Planned Contrast Test Results

Contrast	Means Difference	Standard Error	t	*df*	Prob.
$H_3 : \mu_{ER/QBE} + \mu_{Rel/SQL} > \mu_{ER/SQL} + \mu_{Rel/QBE}$	-16.04	8.87	-1.81	39	0.078

Test Statistics and Results of Tukey HSD Contrasts (results sorted in descending order by mean)

Group	Statistics mean (StDev)	Group			
		Rel/QBE	ER/QBE	ER/SQL	Rel/SQL
Rel/QBE	58.00 (12.57)	-	0.484	0.913	3.120*
ER/QBE	54.64 (11.68)		-	0.320	2.276
ER/SQL	52.50 (13.73)			-	2.290
Rel/SQL	39.82 (16.18)				-

[a] Confidence is measured in a scale anchored at 0% (extremely unconfident) and 100% (extremely confident).
* The mean difference is significant at the 0.05 level.

H4: Perceived Ease-of-Use

Hypothesis 4 (H4) states that ER/QBE and Relational/SQL participants will perceive the combination as easier to use than Relational/QBE and ER/SQL participants. ANOVA with perceived ease-of-use as the dependent variable is reported in table 3, panel D for accounting and MIS participants.

No interaction effect or any main effect was observed for the perceived ease-of-use for the accounting participants. Gender and experience were found to have a significant effect on the perceived ease-of-use (F = 8.26, p = 0.01; F = 4.74, p = 0.03, respectively). Table 2 shows an interaction effect of data model and query language for the MIS participants (F = 13.03, p = 0.001). None of the user characteristics covariates were found to be significant.

No significant mean difference between the four accounting groups is reported (see table 11). For the MIS participants, ER/SQL and Relational/QBE combinations were found to be easier to use than ER/QBE and Relational/SQL (see table 11). H4 is not supported for accounting and MIS groups.

Table 11
Participants Means Comparison of Perceived Ease-of-Use

Planned Contrast Test Results: Accounting

Contrast	Means Difference	Standard Error	t	*df*	Prob.
$H_4 : \mu_{ER/QBE} + \mu_{Rel/SQL} > \mu_{ER/SQL} + \mu_{Rel/QBE}$	-0.36	0.498	-0.73	74	0.467

Test Statistics and Results of Tukey HSD Contrasts (results sorted in descending order by mean)

Group	Statistics mean (StDev)	Group ER/SQL	Rel/QBE	ER/QBE	Rel/SQL
ER/SQL	3.36 (1.20)	-	0.991	0.922	1.053
Rel/QBE	3.04 (0.95)		-	0.000	0.116
ER/QBE	3.04 (0.98)			-	0.108
Rel/SQL	3.00 (1.19)				-

Planned Contrast Test Results: MIS

Contrast	Means Difference	Standard Error	t	*df*	Prob.
$H_4 : \mu_{ER/QBE} + \mu_{Rel/SQL} > \mu_{ER/SQL} + \mu_{Rel/QBE}$	-2.46	0.59	-4.15	39	0.000*

Test Statistics and Results of Tukey HSD Contrasts (results sorted in descending order by mean)

Group	Statistics mean (StDev)	Group ER/SQL	Rel/QBE	ER/QBE	Rel/SQL
ER/SQL	4.97 (0.82)	-	0.562	2.796*	3.882*
Rel/QBE	4.74 (1.05)		-	2.210	3.107*
ER/QBE	3.71 (1.14)			-	0.426
Rel/SQL	3.53 (0.86)				-

[a] Perceived Ease-of-Use is measured using the average score from the instrument's 5 questions using 7-point Likert scale where 1 (very difficult) and 7 (very easy)

* The mean difference is significant at the 0.05 level.

DISCUSSION AND CONCLUSION

The results for the hypothesis related to query accuracy are different for the two types of participants. The hypothesis, based on cognitive fit theory, that the combination of database structure representation and query language affect the efficiency of the end-users is not supported for the accounting group. Even though the four different manipulation groups show no significant differences, the two SQL groups outperformed the two QBE groups for simple queries with the group using a graphical representation of the database (ER model) receiving the highest score. When the task is more complex, the graphical combination (ER/QBE) performed the best. Again, the means differences among the four groups are not significant for complex queries. For novice users, the findings suggest that the ER/SQL combination is the most appropriate for a low level of task complexity. But if multiple tables are needed, resulting in higher task complexity, and the users must aggregate information, then the ER/QBE combination will help accountants completing the task. These findings suggest that the accountants should use a graphical representation of the database structure to help them querying the database and use different query languages based on the complexity of the task.

Gender and experience have a marginal impact of the accounting end-user's performance for complex queries. Females outperform males on complex query accuracy (mean [standard deviation]$_{acc,male}$ = 48.3 [15.9], compared with mean [standard deviation]$_{acc,\ female}$ = 54.3 [14.7]). This finding has been observed in prior studies investigating the impact of end-user gender on information system use (Henry and Stone, 1999) and decision analysis (Palvia and Gordon, 1992). Henry and Stone (1999) found that computer self-efficacy and outcome expectancies which have been shown to influence job performance and job satisfaction were higher for females than for males. Palvia and Gordon (1992) concluded that gender, even though this variable does not affect the performance with a particular mode of decision analysis (e.g., tables, trees, or formulas), is significant for the effectiveness in solving the decision analysis problem. This is similar to the current study's result for gender. Finally, the more educational experience the end-user received, the higher his performance is for complex task (with one computer-related course, mean$_{acc,\ complex}$ = 43.1, and with five computer-related courses, mean$_{acc,\ complex}$ = 66.7). This research points to the continuing need to consider user characteristics in query writing tasks.

For MIS end-users, the type of database structure representation combined with a particular query language has an influence on the query accuracy performance. The interaction is significant for simple queries, but marginally significant for complex queries. This can be explained by the fact that query language type is more important for higher level of task complexity. The results for the hypothesis are significant but opposite to the direction predicted. Cognitive fit theory does not explain the findings. The ER/SQL MIS group outperformed the other three groups. For complex queries, the Relational/QBE group provided the most accurate queries. Not surprisingly, the graphical query tool helps in performing more complex task. This finding confirms the conclusion of the query language studies (Greenblatt and Waxman, 1978; Thomas and Gould, 1975; Yen and Scamell, 1993). Interestingly, gender is marginally significant for complex queries. Female MIS users outperformed the male counterparts (mean [standard deviation]$_{MIS,\ male}$ = 55.8 [17.1], compared with mean [standard deviation]$_{MIS,\ female}$ = 68.8 [15.1]). As mentioned for the accounting end-users, knowing the impact of user characteristics such as gender and educational expertise on task performance will help professionals in their job assignment.

The overall results of the current study for query accuracy confirm the results found by Jih et al. (1989), which showed little difference in the performances using the ER representation

and the relational model with SQL as query language, only for the accounting group. The MIS participants who used the graphical representation along with the SQL language to write simple queries performed the best. This result was found by Davis (1990), which used the same type of end-users. This combination may be the best for efficiency in writing queries, regardless of the end-user's educational background.

For task completion time, the results were not as predicted using the cognitive fit theory. Both accounting and MIS participants performed similarly, though the accounting groups took more time to complete the queries than the MIS groups. These results are not surprising and confirm what the prior studies on query languages found (e.g., Thomas and Gould, 1975; Greenblatt and Waxman, 1978; Yen and Scamell, 1993). Using a graphical query tool helps complete the task faster than with a non-graphical tool such as SQL.

The only difference between the accounting and MIS participants is that the MIS participants required less time to complete the queries. Running the general linear model, with major as one of the independent variables, produces no interaction between query language and major, and no main effect for major exists. Even though no difference in query accuracy performance exists for the accounting end-users, knowing which tool helps in completing the task faster is very useful.

The results for user confidence level were not as predicted based on the cognitive fit theory. This variable is correlated with query accuracy. The MIS participants consistently across groups reported higher level of confidence compared to the accounting groups. The accounting groups do not differ from one another. The difference between the MIS matched groups and the MIS unmatched groups is significant but in the opposite predicted direction. The unmatched groups submitted higher levels of confidence than the matched groups.

Results for perceived ease-of-use were not as predicted. The accounting groups showed no difference in opinion about how easy to use a particular combination is. This finding is in accordance with those found for the other performance variables of the accounting group. The ER/SQL combination was not as cumbersome and frustrating as the other combinations. Similar results were found for the MIS participants but the difference is significant but in the opposite predicted direction. The ER/SQL combination is the best combination. In terms of users' characteristics, the accounting analytic females with high educational experience find a particular combination easier to use than the other type of users. Knowing the users' characteristics will help professionals better assign user friendly combination of tools to end-users.

While previous studies manipulated only the database structure representation or the query language, this research project extended the current literature in accounting and information systems by manipulating both the database structure representation and the query tool. The previous studies were not theoretically based. The current study uses the cognitive fit theory to elaborate hypotheses. Even though using a theory is a step forward to increase the knowledge about database research, the findings cannot be explained by the chosen theory. For each measure of end-user query writing performance, the results are in the opposite direction or the combination of data model and query language does not affect the end-user performance. Some of the results confirm prior research findings.

Unlike prior research, user characteristics, such as professional field, gender, age, educational experience are explicitly included in the research model. The two types of professional fields (accounting and MIS) performed differently for certain measures of performance indicating that end-users will require access to different tools to complete the query writing task. Females and males performed differently. As prior research has recommended and

this study has found, user characteristics are an important factor influencing end-user performance. Future research in this field should include those variables in their model.

The findings have practical implications. While the results from this study do not show that one combination of documentation and query tool is the best of the breed, the methodology of this research and the theories discussed can be utilized to improve both the efficiency and effectiveness of training programs implemented by organizations. Also Professional can increase their performance on an individual level by better understanding what type of documentation and query tool end-users need to improve performance in information retrieval tasks based on the measures of performance (query accuracy, time, confidence, and ease-of-use), and the user characteristics.

REFERENCES

Amer, T. S. (1993). Entity-relationship and relational database modeling representations for the audit review of accounting applications: an experimental examination of effectiveness. *Journal of Information Systems*, 7(Spring), 1-15.

Batra, D., J. A. Hoffer, and R. P. Bostrom (1990). Comparing representations with relational and EER models. *Communications of the ACM*, 33(February), 126-139.

Bonner, S. E. and P. L. Walker (1994). The effects of instruction and experience on the acquisition of auditing knowledge. *The Accounting Review*, 69(January), 157-178.

Borthick, A. F. (1992). Helping users to get the information they want, when they want it, in the form they want it: Integrating the choice and use of information. *Journal of Information Systems*, 6(Fall), v-ix.

Chamberlin, D. D., M. M. Astrahan, K. P. Ezwaran, P. P. Griffiths, R. A. Lorie, J. W. Mehl, P. Reisner, and B. W. Wade (1976). SEQUEL 2: A unified approach to data definition, manipulation, and control. *IBM Journal of Research and Development*, 20(November), 560-575.

Chan, H. C., K. K. Wei, and K. L. Siau (1993). User-database interface: the effect of abstraction levels on query performance. *MIS Quarterly*, 17(December), 441-464.

Cohen, J. (1960). A coefficient of agreement for nominal scales. *Educational and Psychological Measurement*, 20(February), 37-46.

Cronbach, L. J. (1951). Coefficient alpha and the internal structure of tests. *Psychometrika*, 16(September), 297-334.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly*, 13(September), 319-340.

Davis, J. S. (1990). Experimental investigation of the utility of data structure and E-R diagrams in database query. *International Journal of Man-Machine Studies*, 32(July), 449-459.

Dennis, A. R. and T. A. Carte (1998). Using geographical information systems for decision making: Extending cognitive fit theory to map-based presentations. *Information Systems Research*, 9(June), 194-203.

Dickson, G. W., J. A. Senn, and N. L. Chervany (1977). Research in management information systems: The Minnesota experiments. *Management Science*, 23(May), 913-923.

Dunn, C. L. and S. V. Grabski (2002). Empirical research in semantically modeled accounting systems. In *Researching Accounting as an Information Systems Discipline*, edited by V. Arnold and S. G. Sutton (pp. 157-180). Florida: American Accounting Association.

Dunn, C. L. and S. V. Grabski (2001). An investigation of localization as an element of cognitive fit in accounting model representations. *Decision Sciences*, 32(Winter), 55-94.

Flesch, R. F. (1948). A new readability yardstick. *Journal of Applied Psychology*, 32(June), 221-233.

Greenblatt, D. and J. Waxman (1978). A study of three database query languages. In *Databases: Improving Usability and Responsiveness, Proceedings of the International Conference on Databases: Improving Usability and Responsiveness*, edited by B. Schneiderman. New York: Academic Press.

Hayes, D. C. and J. E. Hunton (2001). When querying databases, you've got to ask the right question. *Journal of Accountancy*, 191(February), 35-45.

Henry, J. W. and R. W. Stone (1999). The impacts of end-user gender, education performance, and system use on computer self-efficacy and outcome expectancy. *Southern Business Review*, 25(Fall), 10-16.

Hooper, P. and J. Page (1996). Relational databases: an accountant's primer. *Management Accounting*, 78(October), 48-53.

Jarvenpaa, S. and J. J. Machesky (1989). Data analysis and learning: An experimental study of data modeling tools. *International Journal of Man-Machine Studies*, 31(September), 367-391.

Jih, W. K., D. A. Bradbard, C. A. Snyder, and N. G. A. Thompson (1989). The effects of relational and entity-relationship data models on query performance of end users. *International Journal of Man-Machine Studies*, 31(September), 257-267.

Kincaid, J. and W. McDaniel (1974). *An inexpensive automated way of calculating Flesch Reading Ease scores*. Patent Disclosure Document No. 031350,215 Patent Office, Washington, DC.

Leitheiser, R. L. and S. T. March (1996). The influence of database structure representation on database system learning and use. *Journal of Management Information Systems*, 12(March), 187-213.

Lochovsky, F. H. and D. C. Tsichritzis (1977). User performance considerations in DBMS selection. In *Proceedings of the 1977 ACM SIG-MOD Conference on Management of Data*, edited by D. C. P. Smith (pp. 128-134). Toronto, Canada.

McCarthy, W. E. (1982). The REA accounting model: A generalized framework for accounting systems in a shared data environment. *The Accounting Review*, 57(July), 554-578.

McFadden, F. R., J. A. Hoffer, and M. B. Prescott (1999). *Modern Database Management*. 5th edition. Menlo Park: Addison-Wesley Longman.

Palvia, S. C. and S. R. Gordon (1992). Tables, trees and formulas in decision analysis. *Communications of the ACM*, 35(October), 104-113.

Pratt, J. (1980). The effects of personality on subject's information processing: A comment. *The Accounting Review*, 55(July), 501-506.

Pratt, P. J. (2001). *A Guide to SQL*. 5th edition. Boston: Course Technology.

Pratt, P. J. and J. J. Adamski (2002). *Concepts of Database Management*. 4th edition. Cambridge: Thomson Learning.

Reisner, P. (1981). Human factors studies of database query languages: A survey and assessment. *ACM Computing Surveys*, 13(March), 13-31.

Reisner, P., R. F. Boyce, and D. D. Chamberlin (1975). Human factors evaluation of two data base query languages - SQUARE and SEQUEL. In *Proceedings of the AFIPS National Computer Conference* (pp. 447-452). Anaheim, California.

Sinha, A. P. and I. Vessey (1992). Cognitive fit: An empirical study of recursion and iteration. *IEEE Transactions on Software Engineering,* 18(May), 368-379.

Smelcer, J. B. and E. Carmel (1997). The effectiveness of different representations for managerial problem solving: Comparing tables and maps. *Decision Sciences,* 28(Spring), 391-420.

Thomas, J. C. and J. D. Gould (1975). A psychological study of query by example. In *National Computer Conference Proceedings* (pp. 439-445). New York: AFIPS Press.

Umanath, N. and I. Vessey (1994). Multiattribute data representation and human judgment: A cognitive fit perspective. *Decision Sciences,* 25(September-December), 795-824.

Vessey, I. (1991). Cognitive fit: A theory-based analysis of the graph versus tables literature. *Decision Sciences,* 22(Spring), 219-240.

Vessey, I. (1994). The effect of information presentation on decision making: A cost-benefit analysis. *Information and Management,* 27(August), 103-119.

Vessey, I. and D. Galletta (1991). Cognitive fit: An empirical study of information acquisition. *Information Systems Research,* 2(March), 63-84.

Vessey, I. and R. Weber (1986). Structured tools and conditional logic: An empirical investigation. *Communications of the ACM,* 29(January), 48-57.

Zloof, M. M. (1977). Query-by-Example: A data base language. *IBM Systems Journal,* 16(Winter), 324-343.

Yen, M. Y. and R. W. Scamell (1993). A human factors experimental comparison of SQL and QBE. *IEEE Transactions on Software Engineering,* 19(April), 390-409.

BACKSOURCING: A REVIEW AND THEORETICALLY MOTIVATED VIEW

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ABSTRACT

In view of the varied record of success of IT outsourcing, there has been a discussion of backsourcing, or bringing back outsourced work in-house, as a presumable remedy. In this paper, we review the literature on backsourcing. We attempt to draw a comprehensive portrait of the phenomenon, including its antecedents noted in literature. These range from internal and external changes at the outsourcing firm, as well as problems with the contract discovered later. We extend this literature, offering a new theoretical lens to study backsourcing and outsourcing in a comprehensive manner. In contrast to switching costs, we propose that the path taken by the focal company as it initially outsources IT activities, and the maturity of its Enterprise Architecture, are key criteria which need to be reviewed by business and IT executives when they consider their options. Backsourcing, in and of itself, is not a panacea, in view of limited evidence on its success. The failure of initial outsourcing arrangement is likely to be a symptom of deeper weaknesses within the buyer or focal firm, which limit reversibility and hence the range of options for sourcing.

Keywords: *backsourcing, outsourcing, outsourcing success, modularity, architecture.*

INTRODUCTION

IT outsourcing (also referred to as sourcing) can be defined as "the delegation, through a contractual arrangement, of all or any part of the technical resources, human resources, and the management responsibilities associated with providing IT services to an external vendor" (Clark, Zmud, & McGray, 1995). These outsourcing contracts range from relatively simple, well defined activities or processes to large, complex arrangements known as transformational outsourcing (Linder, 2004). As an organizational practice, outsourcing has been growing over the years. At the renewal stage, or even earlier, the buyer or focal firm considers its options, which range from outsourcing to the same or different vendor, or bringing the outsourced work in-house. Backsourcing refers to the "bringing back" hitherto outsourced activities, specifically referred to IT in IS literature (Hirschheim & Lacity, 1998). As a prerequisite, it would therefore assume an outsourcing arrangement. With growing interest in this topic, a number of researchers have delved into the phenomenon, using a range of methods and theoretical approaches (Benaroch, Dai, & Kauffman, 2010; Veltri, Saunders, & Kavan, 2008). While the motivations of the buyer and vendor firm are different, backsourcing represents a lack of success in the initial outsourcing contract. Therefore, it is a concern to either party. In this paper, we consider some deeper drivers of success in outsourcing (Author 2014) that are also relevant to backsourcing. These drivers are focused on the interests and capabilities of the focal firm.

INDUSTRY BACKGROUND

JP Morgan Chase and its backsourcing after an initial outsourcing deal with IBM (Overby, 2005) estimated at $ 5 billion, is perhaps the most well known example. Overby (2005) details the initial outsourcing arrangement, which was believed to be a "groundbreaking" outsourcing arrangement at the time, with several characteristics of a partnership. In the eyes of an employee at JP Morgan, who transferred to the vendor, this outsourcing arrangement was accompanied with large reorganizations and offshoring. It appears that the vendor was mindful of costs of service. However, we differentiate offshoring from outsourcing, although these are confused in popular press. With the merger of Bank One and JP Morgan Chase, however, a backsourcing arrangement was announced. This led to additional confusion, with overlap in these companies' IT staff. Although this employee moved to a different position 'back' from the vendor to the merged company, it left him low morale and high confusion. It is not clear whether this backsourcing strategy was considered a success. Employee fatigue, reorganization, stagnation, and increased offshoring (Overby, 2005) were the results. Again, while there was 'backsourcing' from a large vendor, JP Morgan had a captive offshore center, which continued to grow. Again, this captive was not technically outsourcing, as it was owned by JP Morgan. Other large and well known backsourcing announcements are shown in Table 1.

Table 1
Examples of backsourcing

Buyer or focal firm	Vendor	Contract dates	Contract value
Bank One	IBM	1998-2002	$ 1.4 billion
Continental Airlines	EDS	1991-1995	$ 2.1 billion
Halifax Bank of Scotland	IBM	2000-2002	$ 1 billion
JP Morgan Chase	IBM	2002-2004	$ 5 billion
Sears	CSC	2004-2005	$ 1.6 billion
UBS	Perot	1996-2006	$ 1.8 billion

RELATED LITERATURE

Extant research has delved into the antecedents of backsourcing (Benaroch, et al., 2010; Kotlarsky & Bognar, 2012; Veltri, et al., 2008; Whitten & Leidner, 2006). Internal or external opportunities, and problems in the contract or vendor (Veltri, et al., 2008) have been uncovered in this research. Changes in executive management, for example a new Chief Information Officer (CIO), and recognition of a new role for IT, are seen in a number of backsourcing cases. External changes include mergers, divestitures and acquisitions. Problems with contract or vendor include cost and service quality related problems that have been seen in cases of outsourcing failures. However, this leaves a number of issues and open questions (Veltri, et al., 2008). Backsourcing is not a panacea, in that recovering skills and capabilities at the focal firm takes time, and is also expensive. As seen with the JP Morgan exemplar, backsourcing is a non event in that it does not necessarily improve employee morale (Veltri, et al., 2008). The

redefinition of "core" IT activity is still very much required. In this sense, there is more resemblance with the issues that arise with outsourcing, instead of a solution. In this vein, literature has considered strategies to minimize differences in the parties' incentives. Benaroch et al. (2010), for example, propose and model flexible service level agreements (SLAs) to align the incentives of the buyer and vendor. The objective, presumably, is to align their incentives closely at the outsourcing stage, and avoid a "breakup" later, which is backsourcing or switching to a new vendor. While switching costs are important (Whitten, Chakrabarty, & Wakefield, 2010), these leave us with expectations (or hopes) for the vendors and in-house IT staff. While the current vendor hopes that switching costs are high, the focal firm hopes that these costs are low. However, it is not clear how either party can manage these costs at the outset, in order to influence them.

RESEARCH QUESTIONS

The literature review leads to the question, as to what are the success factors for backsourcing? Given that it takes place with the prior decision of outsourcing, it is not a 'fresh start'. There is some history at the focal firm, which appears to be ignored in the study of backsourcing. In looking at backsourcing as a standalone phenomenon, extant research has perhaps not touched on deeper issues that affect backsourcing as well as outsourcing. In addition to a clear existence of outsourcing, which could have weakened the focal firm, vagueness of rationales for backsourcing adds to the confusion.

THEORY, FRAMEWORK AND LITERATURE

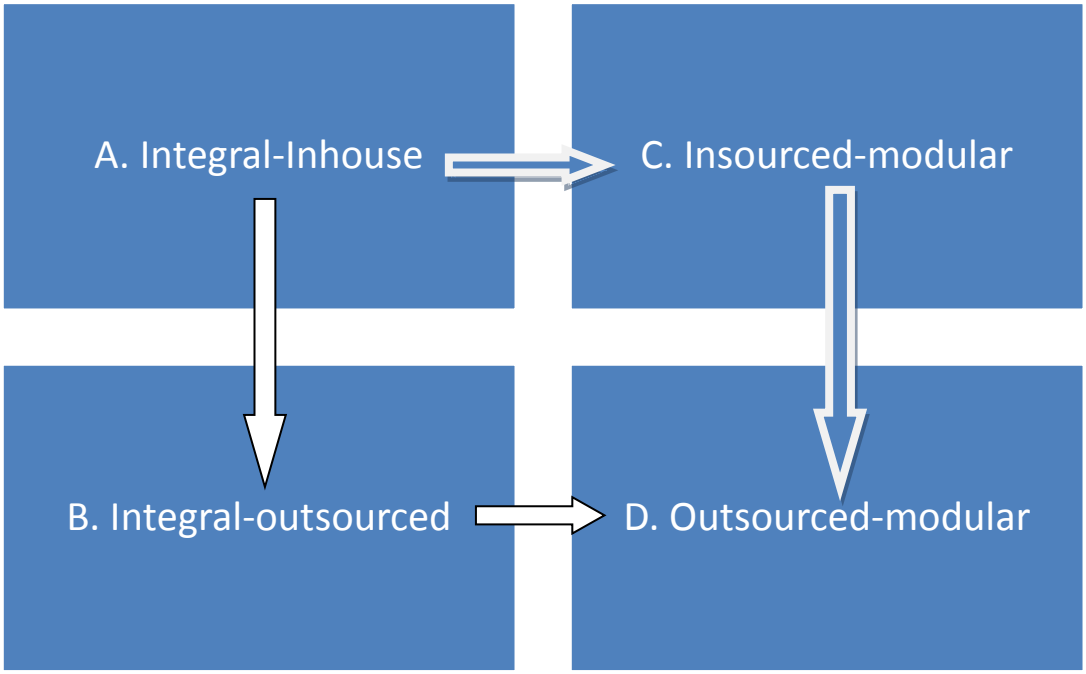
In this section, we introduce well known theory and literature on outsourcing and modularity. These are also referred to as organizational and product architecture (Campagnolo & Camuffo, 2009; Sako, 2003). The positive effect of modularity on outsourcing success follows from the increased efficiency and effectiveness of the outsourcing when modular architectures are used in the IT organization. Modularity permits the combination of limited 'modules' to produce a greater number of services, following the logic of increased variety (Sanchez, 1999). The number and variety of services improves the value of IT organization to users across the firm, given improved customization and fit with user needs. Hence modularity will have direct positive effects on firm performance. On the input side, increased modularity implies increased choice in terms of type and number of suppliers that are potentially available to the focal firm. As vendor markets and individual vendor capabilities continue to evolve (Author 2009), a high level of architectural modularity enables the focal firm to shift and redistribute work more easily among new and existing vendors and makes available a larger set of potential vendors to the focal firm, which is unavailable to its competitors. Some modules are also reusable across activities in the focal firm, which helps to lower IT costs. This reuse is relevant to secular reduction in 'break fix' type of maintenance activities which hog significant IT budgets. This permits lowering costs (Sanchez 1999). Indeed, current outsourcing practices indicate that many IT executives aim to minimize maintenance costs by channeling resulting savings into new application system development and related strategic effects.

Sako (2003) has served as a reference for much of this literature. In particular, she proposes a dynamic model to show how outsourcing and product modularity evolve (Sako, 2003). As shown in Figure 1, it is a grid with integral-modular architecture on the x axis, and insource-outsource on y axis. These axes give rise to 4 quadrants, as shown in the figure. All these paths are assumed to start in quadrant A, insourced-integral, which is the initial state of the focal firm before it improves modularity of architecture, or uses any outsourcing. Sako proposes different paths that emanate from quadrant A. In the first path, A-B, integral architecture is maintained while the task is outsourced. In the context of IT outsourcing, this path is reminiscent of monolithic outsourcing contracts. In these arrangements, IT system was simply outsourced, with little concern for modularity of IT Architecture. In the next step, B-D, which reflects recent development in practice, the vendor could switch the product architecture to modular, and realize additional efficiencies. The second path A-D is a co-evolutionary move, advancing in a single step from A, insourced-integral to D, outsourced-modular quadrant. This path A-D represents strong vendor availability and some focal firm capability to integrate these modules. These conditions support increased modularity of the focal firm IT system. Vendors are relatively interchangeable, if there is a well developed market, and the focal firm has system integration capability. Finally, the focal firm can act as an architect (Campagnolo & Camuffo, 2009) as it first develops its capabilities for increased modularity, without any outsourcing, in path ACD. First, it moves from quadrant A to the adjoining quadrant, C, insourced-modular. This does not involve any outsourcing, only an increase in modularity. In the next step, once increased modularity is achieved, the task is outsourced, to quadrant D, the outsourced-modular quadrant. These paths are summarized in Table 2.

Table 2
Paths to outsourcing and backsourcing

Path	Buyer firm capability	Other characteristics	Backsourcing implications
ABD	Project management	Large vendors, and monolithic outsourcing	No reversibility, lock in with vendor
AD	System integration	Well developed vendor market, with several capable vendors	Limited reversibility, in that vendors are substitutable
ACD	Architecture	Well developed vendor market, as well as internal IT capability	High reversibility, in that vendors are substitutable and backsourcing is an option

Figure 1



In path AD, there is some system integration capability within the focal firm. Although it is dependent on a well developed vendor market, and the focal firm's knowledge of this market, the strength of the focal firm lies in its ability to replace vendors, in case initial outsourcing is not a success. Switching cost across vendors is minimized. However, backsourcing is still costly as regards switching costs.

In the path ACD, the focal firm acts as an architect (Sako, 2003). In this role, it is best able to maintain its system integration and modularization capabilities. Hence, it also has the option to reverse its outsourcing decisions. Switching costs are minimized, in that backsourcing is facilitated. This would appear to be a success factor for backsourcing. Given that success in outsourcing requires deep IT knowledge (Author 2009), it appears that architectural knowledge, paradoxically, improves the odds of success in outsourcing as well as backsourcing.

DISCUSSION AND CONCLUSIONS

Well known theory (Sako, 2003) serves as a general framework for outsourcing as well as backsourcing. In this respect, our analyses answer lingering questions on backsourcing. Specifically to our research question, the existence of architectural knowledge, which is seen with only the reversible path ACD (Sako, 2003) is a success factor in backsourcing. In other paths, more so in ABD, there is little recourse that the focal firm has, once a failure in outsourcing is seen. If followed with backsourcing, it is likely that limited reversibility would restrict focal firm options. It is unlikely that 'success' in any substantive form will result. The story at JP Morgan (Overby, 2005) although anecdotal, serves to confirm this view. Given that a large number of outsourcing arrangements in the past appear to take path ABD, there is little

reversibility built into their outsourcing path. Inevitably, backsourcing is unlikely to succeed. In contrast, ACD is a path that is reversible to the greatest extent. The next best option is AD, which needs strong vendor market knowledge (Author 2009) within the focal firm.

CONTRIBUTIONS, LIMITATIONS, AND FUTURE RESEARCH

The application of Sako (2003) provides a clear direction and theoretical underpinning to research on backsourcing and outsourcing. We answer questions on backsourcing being a non event (Veltri, et al., 2008), limited explanation of switching costs (Whitten, et al., 2010), and questionable success of backsourcing (Overby, 2005). The contribution is that we add a valuable theoretical lens to examine the phenomenon. Given the nascent stage of literature on backsourcing, there is no systematic review of its success. In this respect, it simply rests on an institutional explanation, in that IT executives follow the spirit of the time, whether it is backsourcing or outsourcing. At least the avowed rationale for backsourcing is not very different from that of outsourcing in the first place. Future research can test this view, and empirical tests will add to its rigor.

REFERENCES

Benaroch, M., Dai, Q., & Kauffman, R. J. (2010). Should we go our own way? Backsourcing flexibility in IT services contracts. *Journal of Management Information Systems, 26*(4), 317-358.

Campagnolo, D., & Camuffo, A. (2009). What Really Drives the Adoption of Modular Organizational Forms? An Institutional Perspective from Italian Industry-Level Data. *Industry and Innovation, 16*(3), 291-314.

Clark, T. D., Zmud, R. W., & McGray, G. E. (1995). The outsourcing of Information services: Transforming the nature of the business in the Information industry. *Journal of Information Technology, 8*(1), 5-13.

Hirschheim, R., & Lacity, M. (1998). Backsourcing: An emerging trend. *Journal of Strategic Outsourcing Information, 45*, 78-89.

Kotlarsky, J., & Bognar, L. (2012). Understanding the process of backsourcing: two cases of process and product backsourcing in Europe. *Journal of Information Technology Teaching Cases 2*(2), 79-86.

Linder, J. C. (2004). Transformational Outsourcing. *MIT Sloan Management Review, 45*(2), 52.

Overby, S. (2005). Backsourcing pain. *CIO-FRAMINGHAM MA-, 18*, 64.

Sako, M. (2003). Modularity and outsourcing: The nature of co-evolution of product architecture and organisation architecture in the global automotive industry *The business of systems integration* (pp. 229-253).

Sanchez, R. (1999). Modular Architectures in the Marketing Process. *Journal of Marketing, 63*(4).

Veltri, N. F., Saunders, C. S., & Kavan, C. B. (2008). Information systems backsourcing: correcting problems and responding to opportunities. *California Management Review, 51*(1), 50-76.

Whitten, D., Chakrabarty, S., & Wakefield, R. (2010). The strategic choice to continue outsourcing, switch vendors, or backsource: Do switching costs matter? *Information & Management, 47*(3), 167-175.

Whitten, D., & Leidner, D. (2006). Bringing IT Back: An Analysis of the Decision to Backsource or Switch Vendors. *Decision Sciences, 37*(4), 605-621.

MINIMIZING TOTAL WEIGHTED COMPLETION TIME ON BATCH PROCESSING MACHINES

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ABSTRACT

This research is motivated by a scheduling problem found in the burn-in operations at the final testing stage in semiconductor manufacturing, where burn-in ovens can be modeled as parallel batch processing machines. We consider the problem of minimizing total weighted completion time, which can be interpreted as minimizing the total holding cost of work-in-process inventory. We formulate the problem as a nonlinear integer programming model. Given that this problem is NP-hard, we then propose a genetic algorithm, based on random keys encoding, to heuristically solve the problem. Computational results show that the genetic algorithm consistently outperforms a standard mathematical programming solver in terms of solutions and computation times.

INTRODUCTION

The diffusion of the Internet and related applications has brought new markets to semiconductor manufacturing companies. After the big slump in 2008 and 2009, sales of semiconductors rebounded and hit a record high in 2013. Besides those established categories such as personal computers, demand has been growing strong for chips in smartphones, cars, and the so-called "Internet of Things," a term referring to adding intelligence to many everyday devices, such as door locks, light bulbs, and thermostats (Clark, 2014). Meanwhile, the growth in demand for chips has been accompanied by intense competition between semiconductor manufacturers. In order to gain and sustain competitive advantage, many companies strive to provide high quality products that satisfy customer needs while simultaneously reducing production costs.

In this paper we study the operations scheduling problem from the semiconductor industry. The chips that have been used in computers, cars, appliances, and virtually all electronic equipment are manufactured in semiconductor fabrication plants (commonly called fabs). A typical fab has several hundred extremely expensive processing tools, each of which can cost $10 million, and the cost of building a new fab could be over $1 billion, with values as high as $5 billion not being uncommon. Due to the high capital investment and operating costs, it is critical to run the fabs efficiently. A cost-effective approach is to fully utilize the processing tools through efficient scheduling of the operations.

There are four major steps in semiconductor manufacturing: wafer fabrication, wafer probe, assembly or packaging, and final testing (Uzsoy et al., 1992). After a chip is assembled, it then proceeds to the final testing step. The scheduling problem studied in this paper is motivated by the burn-in operations that take place during the final testing. The purpose of the burn-in test is to subject the chips to electrical and thermal stress, so that any chip out of specification can be

identified and removed from the lot. In the burn-in test, chips are loaded onto boards, which are then placed into burn-in ovens. The ovens are maintained at a constant high temperature for a period of time. In practice, the boards are assigned to the lots of chips waiting for burn-in test off-line (Lee et al., 1992), so each board can be treated as a single job. In order to utilize the oven capacities efficiently, boards are grouped together into batches for processing. Multiple ovens are typically operated in parallel. Thus, burn-in ovens can be modeled as parallel nonidentical batch processing machines.

The burn-in time for each chip, dictated by the test specification, is known *a priori*. To ensure the quality of the product, a chip can be kept in the oven longer than its specified burn-in time, but not taken out from the oven before the burn-in time has elapsed. Therefore, the processing time of a batch is determined by the longest processing time of all the chips in the batch. The processing times in burn-in test are, in general, extremely long compared to other tests (Lee et al., 1992), so the burn-in test is frequently the bottleneck in the final testing stage. Since the burn-in operations are near the end of the manufacturing process, the efficient scheduling of burn-in operations to minimize flow time and work-in-process inventory (WIP) is crucial to the overall performance of a semiconductor manufacturing company. This motivates us to use the performance measure of total weighted completion time (TWC), defined as $\text{TWC} := \sum w_j C_j$, where C_j is the completion time of job *j* and the weight w_j represents the cost of holding job *j* in the system for one unit of time. This measure provides an indication of the total holding or inventory cost of WIP incurred by the schedule. We seek to minimize the total weighted completion time, as a surrogate to minimize the total inventory costs.

We consider the burn-in operations in which ovens have nonidentical capacities, and jobs (boards) have dynamic arrival times (i.e., not all jobs are ready for processing at time zero), nonidentical capacity requirements (i.e., different job sizes), and different processing (burn-in) times. Following the three-field notation of Pinedo (2002), we denote this scheduling problem as $Rm \mid r_j, batch \mid \sum w_j C_j$, where *Rm* represents *m* unrelated parallel machines (a manufacturing environment in which machines can run at different rates and an individual machine can process different jobs at different rates), and r_j denotes the ready time of job *j*. Given *n* jobs with nonidentical capacity requirements to be scheduled on a single batch processing machine, Uzsoy (1994) showed that $1 \mid r_j, batch \mid \sum C_j$ is NP-hard and that even the simpler version with identical processing times is also NP-hard. Adding parallel unrelated (nonidentical) batch processing machines, dynamic job arrivals, and weights to the completion times further complicates the problem. Therefore, the scheduling problem in this research is also NP-hard. It is widely believed that there are no efficient polynomial time algorithms for NP-hard problems, and hence developing heuristic methods to quickly obtain near-optimal solutions is a useful approach. We first formulate the scheduling problem as a nonlinear integer programming model. Since the problem is NP-hard, we propose a genetic algorithm to heuristically solve it within reasonable computation times. It should be noted that although this research is motivated by burn-in operations in semiconductor manufacturing industry, batch processing machines are also found in a wide range of applications, such as metalworking and chemical processes.

The rest of the paper is organized as follows. In the next section we review previous research on scheduling batch processing machines. Afterwards, we present a mathematical formulation of the problem and provide a baseline approach using a standard mathematical programming solver. Then, a genetic algorithm is proposed to heuristically solve the problem, followed by computational experiments. Finally, we conclude the paper with a summary of main findings and a discussion of future research.

LITERATURE REVIEW

The study of scheduling batch processing machines has received much attention among researchers. Lee et al. (1992) examined the problem of scheduling burn-in operations in semiconductor manufacturing, where burn-in ovens are modeled as batch processing machines. They presented efficient algorithms for minimizing a number of performance measures on a single batch processing machine. They also presented heuristics for minimizing makespan on parallel identical batch processing machines. Uzsoy (1994) studied the problems of scheduling a single batch processing machine with nonidentical capacity requirements to minimize total completion time and makespan. He showed that both problems are NP-hard and developed heuristics for both, as well as a branch and bound algorithm for the total completion time problem. Uzsoy and Yang (1997) considered the problem of scheduling jobs with static arrivals (i.e., all jobs are available for processing at time zero) on a single batch processing machine to minimize total weighted completion time. They presented a branch and bound algorithm to obtain optimal solutions and also developed a number of heuristics and evaluated their performances through computational experiments. Dupont and Dhaenens-Flipo (2002) studied the problem of scheduling jobs with nonidentical capacity requirements on a single batch processing machine to minimize the makespan. They provided a branch and bound algorithm for small-scale problems and used enumeration as a heuristic method for large-scale problems. Koh et al. (2004) studied the problem of scheduling parallel identical batch processing machines with nonidentical capacity requirements. They developed a number of heuristics and genetic algorithms to minimize makespan, total completion time, and total weighted completion time, and evaluated the performances of the heuristics and genetic algorithms through computational experiments. Malve and Uzsoy (2007) considered the problem of minimizing maximum lateness on parallel identical batch processing machines with dynamic job arrivals. They proposed a genetic algorithm, based on random keys encoding of Bean (1994), to heuristically solve the problem. Biskup et al. (2008) studied the problem of scheduling jobs on parallel identical machines to minimize total tardiness. They developed heuristic algorithms and evaluated the performances of the algorithms through computational experiments. Condotta et al. (2010) studied the problems of scheduling jobs on single and parallel identical batch processing machines under the assumption that all jobs have equal processing times and proposed a number of algorithms to minimize the maximum lateness. Selvarajah et al. (2013) considered the problem of scheduling single batch processing machine with dynamic job arrival times to minimize the sum of weighted flow times and delivery costs. They presented an approximate polynomial time algorithm for the simple case and a metaheuristic algorithm for the general case.

All the research discussed above addressed batch scheduling problems with either a single machine or parallel identical machines. In this paper we consider the more general batch scheduling problem with parallel nonidentical machines, dynamic job arrival times, and nonidentical capacity requirements.

MATHEMATICAL MODEL FORMULATION

In this section we formulate a mathematical programming model, which is an optimal algorithm to the scheduling problem. Before we present the mathematical model, we make the following assumptions about the problem:

a) The setup times of the machines are negligible.
b) Once processing of a batch starts, it cannot be preempted; no chip can be removed from or introduced to the burn-in oven until the processing of the entire batch is completed.
c) All data, such as job arrival times and processing times, are deterministic and known *a priori*.

A list of notation for the mathematical model is as follows:

Set and Indexes:

J	set of jobs ($\|J\|$ is the number of jobs);
M	set of machines ($\|M\|$ is the number of machines);
B	set of batches ($\|B\|$ is the number of batches);
j	index of job, $j \in J$;
m	index of machine, $m \in M$;
b	index of batch, $b \in B$.

Parameters:

K_m	capacity of machine m;
s_j	size (i.e., capacity requirement) of job j;
w_j	weight (unit holding cost) of job j;
p_j	processing time of job j;
r_j	ready time of job j (the earliest time when job j can begin its processing).

Variables:

$x_{jm[b]}$	binary, 1 if job j is assigned to batch b and processed by machine m, 0 otherwise;
$R_{m[b]}$	ready time of batch b processed by machine m;
$P_{m[b]}$	processing time of batch b on machine m;
C_j	completion time of job j;
$F_{m[b]}$	completion time of batch b processed by machine m.

The problem can be formulated as the following nonlinear integer programming model:

$$\min \ \text{TWC} := \sum_{j \in J} w_j C_j \tag{1}$$

subject to

$$\sum_{j \in J} s_j x_{jm[b]} \le K_m \qquad \forall m \in M, b \in B \tag{2}$$

$$\sum_{m \in M} \sum_{b \in B} x_{jm[b]} = 1 \qquad \forall j \in J \tag{3}$$

$$P_{m[b]} \ge p_j x_{jm[b]} \qquad \forall j \in J, m \in M, b \in B \tag{4}$$

$$R_{m[b]} \ge r_j x_{jm[b]} \qquad \forall j \in J, m \in M, b \in B \tag{5}$$

$$F_{m[b]} \ge F_{m[b-1]} + P_{m[b]} \qquad \forall m \in M, b \in B \tag{6}$$

$$F_{m[b]} \ge R_{m[b]} + P_{m[b]} \qquad \forall m \in M, b \in B \tag{7}$$

$$C_j \ge F_{m[b]} x_{jm[b]} \qquad \forall j \in J, m \in M, b \in B \tag{8}$$

$$x_{jm[b]} = 0 \text{ or } 1 \qquad \forall j \in J, m \in M, b \in B \tag{9}$$

Objective (1) minimizes the total weighted completion time. Constraint (2) specifies that the capacity of each machine cannot be exceeded. Constraint (3) ensures that job *j* is assigned to exactly one batch and processed on one machine. Constraint (4) determines the processing time of a batch, which equals the longest processing time of all jobs in the batch. Constraint (5) determines the time when a batch is ready for processing. Constraints (6) and (7) jointly determine the completion time of a batch. Constraint (8) determines the completion time of each job. Constraint (9) enforces binary restrictions on each of the decision variable *x*.

The nonlinear integer programming model was coded in AMPL and solved by CPLEX, a standard mathematical programming solver for linear and mixed integer programming models. The AMPL/CPLEX implementation serves as our baseline approach to the problem. When implemented in CPLEX, the nonlinear constraint in (8) was converted to a linear constraint with the "big M" method.

Preliminary experiments showed that for some small (20-job 2-machine) problem instances, CPLEX was unable to find an optimal solution within two hours on a computer with a 2.50 GHz Intel Core i5-2520M CPU, 16 GB RAM, and the Windows 7 64-bit operating system. As discussed in the Introduction section, this problem is NP-hard. Therefore, the optimal solution to a problem of any practical size cannot likely be obtained within reasonable computation times. In the next section we propose a genetic algorithm to heuristically solve the problem.

A GENETIC ALGORITHM APPROACH

Genetic algorithm (GA) is an adaptive search heuristic based on the mechanism of natural evolution. The evolution in a GA starts with a population of randomly generated

chromosomes. Each chromosome represents a solution to the optimization problem being solved. The population in each iteration of the evolution is called a *generation*. In each generation, the fitness of each chromosome (usually expressed as the objective value of the optimization problem) in the population is evaluated. The GA applies the paradigm of *survival-of-the-fittest* through operators such as *selection*, *crossover*, and *mutation*, to evolve the population from one generation to the next. The algorithm usually terminates when either the maximum number of generations has been reached, or a satisfactory solution has been found. For additional information about GA, see Goldberg (1989).

To apply GA to a problem, a chromosomal encoding of the solution must be carefully devised, since the encoding has direct impact on the performance of the GA. Given a problem, often the difficulty stems from the encoding of the solutions so that crossovers of feasible solutions result in feasible ones as offspring. Based on the structure of our problem, we use the genetic algorithm, based on the random keys encoding of Bean (1994), as the solution approach. The random keys genetic algorithm (RKGA) encodes a solution with random numbers, uniformly drawn from the interval (0, 1), as sort keys to decode the solution. The encodings of the solutions are evaluated in the objective evaluation function in a way that eliminates the feasibility issue. RKGA has been applied to many optimization problems, see, e.g., Norman and Bean (1999, 2000), Wang and Uzsoy (2002), Kurz and Askin (2004), Gonçalves et al. (2005), Snyder and Daskin (2006), Mendes et al. (2009), and Gonçalves et al. (2011).

The RKGA uses the genetic operators *elitist reproduction*, *Bernoulli crossover*, *post-tournament selection*, and *immigration*, as described in Bean (1994) and Norman and Bean (1999). In the following we elaborate how RKGA is used to address the scheduling problem.

Encoding

We adopt the random keys encoding scheme, as introduced in Bean (1994), for our problem. A chromosome for the *n*-job *m*-machine scheduling problem has *n* genes. To obtain the gene for each job, generate an integer randomly sampled from {1, …, |*M*|}, and add a uniform random number drawn from the interval (0, 1). This real number serves as a random key for the job. The integer part of the random key is interpreted as the machine assignment for the job, and the fractional parts of all the random keys associated with each machine are sorted to provide the job sequence on each machine.

Initialization

Randomly generate a population of chromosomes to form the initial generation, and evaluate the objective value for each chromosome (solution) using `Procedure SCHED-EVAL` outlined next.

Schedule Construction and Evaluation

The procedure for constructing a schedule and evaluating for the objective (which is TWC in our problem), denoted by `Procedure SCHED-EVAL`, is as follows.

a) Sort the random keys for the n jobs in increasing order.
b) Determine the machine assignment for each job and the sequence of jobs on each machine.
c) Form batches from the job sequence on each machine such that its capacity is not exceeded.
d) Determine the processing time, the start and completion times, for each batch.
e) Determine the completion time for each job and calculate TWC.

Elitist Reproduction

For each iteration, we copy a number of best chromosomes from one generation to the next (we call these copied chromosomes *clones*), so that the best solution is monotonically improving. This is called elitist strategy in Goldberg (1989).

Bernoulli Crossover

Randomly select two chromosomes as parents from the current generation. At each gene, toss a biased coin to determine which parent will contribute its allele to the two offspring. For example, we may specify that a head selects the allele from Parent 1 for Offspring 1, and a tail selects the allele from Parent 2 for Offspring 2. This approach, called parameterized uniform crossover in Spears and De Jong (1991), and Bernoulli crossover in Norman and Bean (1999), is different from the traditional one- or two-point crossover. See Bean (1994) for an example of the Bernoulli crossover.

Post-tournament Selection

Post-tournament selection (Norman & Bean, 1999) is used along with Bernoulli crossover to fill the next generation. The two offspring created from crossover are evaluated, and only the one with better fitness (lower TWC value in our problem) is allowed to enter the new generation.

Immigration

We use the genetic operator *immigration*, as described in Bean (1994), to diversify the search space. In each generation, a small number of new chromosomes are randomly generated as immigrants. Immigration avoids premature convergence to a local optimum that can be caused by reproduction and crossover, and ensures that the solution space has been searched to a reasonable extent.

Pseudo-code for the RKGA

The pseudo-code for the RKGA is as follows:

1. Set parameters for the algorithm: maximum number of generations (N_{max}); population size (N_{pop}); number of clones (N_c); number of immigrants (N_m).
2. Create initial generation of chromosomes with population size N_{pop}.
3. Evaluate the objective value per `Procedure SCHED-EVAL` for each chromosome.

4. Sort old population by objective value.
5. Copy N_c best chromosomes to the next generation (Elitist Reproduction).
6. For remainder of the population:
   a) Randomly select two parents from old population.
   b) Employ Bernoulli crossover.
   c) Employ post-tournament selection for the offspring.
7. Replace N_m worst chromosomes with immigrants.
8. Evaluate objective values for the immigrants per **`Procedure SCHED-EVAL`**.
9. Update the best solution found so far.
10. Repeat steps 4–9 until generation N_{max} has been reached.

COMPUTATIONAL EXPERIMENTS

We design a set of computational experiments to evaluate the performance of the proposed genetic algorithm. The RKGA was coded in C++ and run on a computer with a 2.50 GHz Intel Core i5-2520M CPU, 16 GB RAM, and the Windows 7 64-bit operating system. The mathematical programming model was coded in AMPL and solved by CPLEX 12.6 on the same computer.

The data were randomly generated, in a manner similar to that in Akturk and Ozdemir (2001), for the experiments. We consider the manufacturing environment with two and four parallel batch processing machines, although our approach applies to a setting with any number of machines. Machine capacities were randomly drawn from $U[8, 12]$, where $U[a, b]$ denotes a discrete uniform distribution between a and b. Three levels of the number of jobs were selected to represent different problem scales: small (40 jobs), medium (60 jobs), and large (100 jobs). Two levels of job sizes (capacity requirements) were selected: $U[1, 4]$ and $U[2, 8]$. The weights (unit holding costs) of jobs were randomly generated from $U[1, 5]$, with value of 1 representing the lowest unit holding costs (for simple, cheap parts) and 5 representing the highest unit holding costs (for important, expensive parts). The job processing times spread over $U[1, 10]$, indicating a wide range of processing time requirements for different parts. The job ready time, r_j, was randomly generated from $U\left[0, \left\lfloor C^*_{\max} \right\rfloor\right]$, where $\lfloor a \rfloor$ denotes the largest integer not greater than a, and $C^*_{\max}$ is an estimate of the makespan. We set

$$C^*_{\max} = \frac{\bar{s}\sum_j p_j}{\sum_m K_m}$$

where $\bar{s} = \sum_j s_j / |J|$ is the average job size. There are 12 unique factor combinations in the experiments. Table 1 summarizes the experimental design. Five replications were made for each factor combination, yielding a total of 60 randomly generated problem instances.

For the RKGA, we empirically choose the parameters such as the maximum number of generations (N_{max}), population size (N_{pop}), number of clones (N_c), and number of immigrants (N_m). After a few pilot runs, we fix these parameters and use the same set of parameters for all subsequent experiments. The parameter settings for the RKGA are as follows: N_{max} = 1,000, N_{pop} = 1,000, N_c = 200, and N_m = 10. For each of the 60 problem instances, RKGA was run 10 replications, each with a different random seed.

For the AMPL/CPLEX implementation, preliminary experiments showed that for some 40-job 2-machine problem instances, CPLEX failed to find an optimal solution after two hours, and that the solutions showed very little or no improvements over those from the experiments with one hour of run time. Thus, we decided to run CPLEX with one hour (i.e., 3,600 seconds) time limit for all the 60 problem instances.

Table 1: Factors and Levels in the Experiments

Factors	Levels	Values
Number of machines, $\|M\|$	2	2,4
Machine capacity, K_m	1	U[8,12]
Number of jobs, $\|J\|$	3	40, 60, 100
Job size, s_j	2	U[1,4], U[2,8]
Weight, w_j	1	U[1,5]
Processing time, p_j	1	U[1,10]
Ready time, r_j	1	$U\left[0,\left\lfloor C^*_{\max}\right\rfloor\right]$

Table 2 and Table 3 present the computational results for all the 60 problem instances. Table 2 shows the results for the two-machine setting, while Table 3 for the four-machine setting. In the tables, column [1] is the unique ID of the problem instance. Column [2] is the factor combination for the number of jobs and the job size. For example, (60, s_2) denotes the number of jobs is 60, and the job size is at level 2 (i.e., sampled from U[2, 8]). Column [3] reports the minimum TWC over the 10 different random seeds, while column [4] is the average run time (in seconds) for the 10 random seeds. Columns [5] and [6] report in which generation the best solution was first found and the time (in seconds) required to achieve that solution. Columns [7] and [8] report the TWC and the run time (in seconds) from CPLEX. Column [9] is the percentage improvement realized through RKGA over CPLEX in terms of TWC. The percentage improvement is calculated by $(TWC^C - TWC^R)/TWC^C$, where TWC^C is the TWC obtained from CPLEX, while TWC^R is the TWC obtained from RKGA.

As can be seen from Table 2 and Table 3, RKGA outperformed CPLEX in terms of TWC for all the 60 problem instances. Specifically, in the two-machine setting the average improvement of RKGA over CPLEX is 10.85% for small problems (40 jobs), 32.65% for medium problems (60 jobs), and 48.03% for large problems (100 jobs), while in the four-machine setting the average improvement is even greater; it is 16.97% for small problems, 32.81% for medium problems, and 54.51% for large problems.

For all the 60 problem instances, CPLEX failed to find the optimal solution within the one hour time limit. By contrast, RKGA took much less computation times (while achieved better solutions) than CPLEX. For example, in the two-machine setting the average computation time of RKGA is about 8 seconds for small problems, 13 seconds for medium problems, and 23 seconds for large problems. We observe the similar pattern of computation times in the four-machine setting. Also notice that how RKGA was able to quickly identify the best solution. For example, in the two-machine setting it took about an average of 2 seconds to find the best solution for the small problems, 7 seconds for the medium problems, and 16 seconds for the large problems.

Table 2: Computational Results for Random Problem Instances (Two Machines)								
Prob.	Factor	RKGA		Best Solution		CPLEX		Improv.
		TWC	Sec.	Gen.	Sec.	TWC	Sec.	(%)
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]
1	(40, s_1)	1,703	8.21	87	0.80	1,999	3,600	14.81
2	(40, s_1)	2,183	8.01	80	0.75	2,470	3,600	11.62
3	(40, s_1)	1,944	7.85	92	0.86	2,199	3,600	11.60
4	(40, s_1)	1,886	7.99	80	0.75	2,097	3,600	10.06
5	(40, s_1)	1,787	7.98	461	3.81	1,902	3,600	6.05
6	(40, s_2)	3,408	8.21	169	1.54	3,889	3,600	12.37
7	(40, s_2)	3,756	8.65	205	1.97	4,338	3,600	13.42
8	(40, s_2)	2,992	8.02	820	6.57	3,393	3,600	11.82
9	(40, s_2)	2,700	8.11	671	5.46	2,942	3,600	8.23
10	(40, s_2)	2,787	8.28	198	1.76	3,047	3,600	8.53
11	(60, s_1)	3,680	12.56	235	3.18	5,095	3,600	27.77
12	(60, s_1)	3,635	12.52	932	11.45	5,731	3,600	36.57
13	(60, s_1)	3,944	12.64	535	6.97	5,600	3,600	29.57
14	(60, s_1)	3,310	12.55	760	9.83	5,074	3,600	34.77
15	(60, s_1)	3,305	12.67	229	3.11	5,170	3,600	36.07
16	(60, s_2)	4,702	13.08	170	2.51	6,552	3,600	28.24
17	(60, s_2)	7,214	13.12	413	5.77	11,918	3,600	39.47
18	(60, s_2)	7,725	13.25	201	2.93	11,017	3,600	29.88
19	(60, s_2)	5,423	13.10	981	12.79	7,995	3,600	32.17
20	(60, s_2)	5,863	12.93	948	12.39	8,616	3,600	31.95
21	(100, s_1)	9,006	21.98	360	8.60	15,618	3,600	42.34
22	(100, s_1)	10,053	22.61	958	22.01	19,945	3,600	49.60
23	(100, s_1)	9,443	21.98	288	7.08	17,197	3,600	45.09
24	(100, s_1)	9,089	21.89	767	17.08	16,849	3,600	46.06
25	(100, s_1)	9,041	22.04	372	8.58	18,407	3,600	50.88
26	(100, s_2)	20,726	23.20	936	21.84	35,390	3,600	41.44
27	(100, s_2)	19,588	23.17	904	21.28	38,347	3,600	48.92
28	(100, s_2)	12,419	22.68	664	15.29	27,400	3,600	54.68
29	(100, s_2)	16,126	23.36	677	15.88	32,710	3,600	50.70
30	(100, s_2)	15,047	22.88	909	20.78	30,444	3,600	50.57

The computational experiments also demonstrate two important merits of RKGA. First, computation time is quite consistent for the same group (i.e., small, medium, or large) of problems. Second, computation time increases in a reasonable manner as problem size increases, that is, computation time for RKGA is predictable. The RKGA appears to be a very robust approach for our problem.

Table 3: Computational Results for Random Problem Instances (Four Machines)								
Prob.	Factor	RKGA		Best Solution		CPLEX		Improv.
		TWC	Sec.	Gen.	Sec.	TWC	Sec.	(%)
[1]	[2]	[3]	[4]	[5]	[6]	[7]	[8]	[9]
31	(40, s_1)	1,314	8.53	882	7.58	1,577	3,600	16.68
32	(40, s_1)	1,456	8.57	98	0.97	1,701	3,600	14.40
33	(40, s_1)	1,171	8.50	97	1.14	1,409	3,600	16.89
34	(40, s_1)	1,204	8.50	87	0.84	1,540	3,600	21.82
35	(40, s_1)	1,338	8.70	121	1.16	1,648	3,600	18.81
36	(40, s_2)	1,942	8.94	111	1.15	2,320	3,600	16.29
37	(40, s_2)	1,791	8.91	314	2.92	2,199	3,600	18.55
38	(40, s_2)	2,145	8.81	403	3.67	2,518	3,600	14.81
39	(40, s_2)	1,764	8.93	103	1.08	2,142	3,600	17.65
40	(40, s_2)	1,707	9.00	244	2.36	1,979	3,600	13.74
41	(60, s_1)	2,548	13.44	694	9.41	3,576	3,600	28.75
42	(60, s_1)	1,760	13.78	134	2.11	2,380	3,600	26.05
43	(60, s_1)	3,313	13.61	614	8.49	4,940	3,600	32.94
44	(60, s_1)	2,297	13.66	453	6.35	3,751	3,600	38.76
45	(60, s_1)	2,552	13.65	141	2.18	3,920	3,600	34.90
46	(60, s_2)	4,712	14.01	142	2.40	6,486	3,600	27.35
47	(60, s_2)	3,429	13.86	239	3.62	5,655	3,600	39.36
48	(60, s_2)	3,616	14.00	125	2.04	5,520	3,600	34.49
49	(60, s_2)	4,285	14.05	322	4.77	6,367	3,600	32.70
50	(60, s_2)	3,470	14.19	249	3.81	5,167	3,600	32.84
51	(100, s_1)	4,924	23.52	568	14.07	10,531	3,600	53.24
52	(100, s_1)	5,123	23.58	916	22.34	9,623	3,600	46.76
53	(100, s_1)	5,442	23.87	746	18.08	12,909	3,600	57.84
54	(100, s_1)	5,500	23.76	420	10.58	10,656	3,600	48.39
55	(100, s_1)	5,348	24.00	858	21.03	10,904	3,600	50.95
56	(100, s_2)	8,347	24.87	753	18.88	17,198	3,600	51.47
57	(100, s_2)	8,126	24.84	935	23.82	21,691	3,600	62.54
58	(100, s_2)	9,323	25.01	373	10.28	22,120	3,600	57.85
59	(100, s_2)	9,226	25.05	784	20.31	23,247	3,600	60.31
60	(100, s_2)	9,451	25.03	830	21.47	21,373	3,600	55.78

CONCLUSIONS

In this paper we considered the scheduling problem of minimizing total weighted completion time, as a proxy measure of minimizing total holding costs of work-in-process inventories, on parallel nonidentical batch processing machines. We studied this problem in the

context of the semiconductor burn-in operations, which is of practical interest to semiconductor manufacturing and many other industries.

We first formulated the problem as a nonlinear integer programming model. Given that the problem is NP-hard, we proposed a genetic algorithm, based on random keys encoding, to heuristically solve it. Through extensive computational experiments, we showed that the proposed genetic algorithm consistently outperformed a standard mathematical programming solver in terms of solutions and computation times.

A number of directions for future research are apparent from this study. First, a tight lower bound on the total weighted completion time will be useful as a benchmark for evaluating the proposed genetic algorithm. Second, other heuristics could be developed as well to address the problem. Finally, this research could be adapted to include sequence dependent setup times, so that the assumption of negligible setup times can be relaxed.

REFERENCES

Akturk, M.S. & D. Ozdemir (2001). A new dominance rule to minimize total weighted tardiness with unequal release dates. *European Journal of Operational Research*, 135(2), 394-412.

Bean, J. C. (1994). Genetic algorithms and random keys for sequencing and optimization. *ORSA Journal on Computing*, 6(2), 154-160.

Biskup, D., J. Herrmann & J.N.D. Gupta (2008). Scheduling identical parallel machines to minimize total tardiness. *International Journal of Production Economics*, 115(1), 134-142.

Clark, D. (2014). Chip sales tracking toward another record in 2014. *The Wall Street Journal*, August 4, 2014. Retrieved on August 10, 2014, from http://online.wsj.com/articles/chip-sales-tracking-toward-another-record-in-2014-1407184216.

Condotta, A., S. Knust & N.V. Shakhlevich (2010). Parallel batch scheduling of equal-length jobs with release and due dates. *Journal of Scheduling*, 13(5), 463-477.

Dupont, L. & C. Dhaenens-Flipo (2002). Minimizing the makespan on a batch machine with non-identical job sizes: an exact procedure. *Computers & Operations Research*, 29(7), 807-819.

Goldberg, D.E. (1989). *Genetic Algorithms in Search, Optimization, and Machine Learning*. Reading, MA: Addison-Wesley.

Gonçalves, J.F., J.J.M. Mendes & M.G.C. Resende (2005). A hybrid genetic algorithm for the job shop scheduling problem. *European Journal of Operational Research*, 167, 77-95.

Gonçalves, J. F., M.G.C. Resende & J.J.M. Mendes (2011). A biased random-key genetic algorithm with forward-backward improvement for the resource constrained project scheduling problem. *Journal of Heuristics*, 17(5), 467-486.

Koh, S.G., P.H. Koo, J.W. Ha & W.S. Lee (2004). Scheduling parallel batch processing machines with arbitrary job sizes and incompatible job families. *International Journal of Production Research*, 42, 4091-4107.

Kurz, M.E. & R.G. Askin (2004). Scheduling flexible flow lines with sequence-dependent setup times. *European Journal of Operational Research*, 159(1), 66-82.

Lee, C.Y., R. Uzsoy & L.A. Martin-Vega (1992). Efficient algorithms for scheduling semiconductor burn-in operations. *Operations Research*, 40, 764-775.

Malve, S. & R. Uzsoy (2007). A genetic algorithm for minimizing maximum lateness on parallel identical batch processing machines with dynamic job arrivals and incompatible job families. *Computers & Operations Research*, 34(10), 3016-3028.

Mendes, J.J.M., J.F. Gonçalves & M.G.C. Resende (2009). A random key based genetic algorithm for the resource constrained project scheduling problem. *Computers & Operations Research*, 36(1), 92-109.

Norman, B.A. & J.C. Bean (1999). A genetic algorithm methodology for complex scheduling problems. *Naval Research Logistics*, 46, 199-211.

Norman, B.A. & J.C. Bean (2000). Scheduling operations on parallel machine tools. *IIE Transactions*, 32, 449-459.

Pinedo, M. (2002). *Scheduling: Theory, Algorithms, and Systems (2nd ed.)*. Upper Saddle River, NJ: Prentice-Hall.

Selvarajah, E., G. Steiner & R. Zhang (2013). Single machine batch scheduling with release times and delivery costs. *Journal of Scheduling*, 16(1), 69-79.

Snyder, L. & M. Daskin (2006). A random-key genetic algorithm for the generalized traveling salesman problem. *European Journal of Operational Research*, 174, 38-53.

Spears, W.M. & K.A. De Jong (1991). On the virtues of parameterized uniform crossover. *Proceedings of the 4th International Conference on Genetic Algorithms*, 230-236.

Uzsoy, R. (1994). Scheduling a single batch processing machine with nonidentical job sizes. *International Journal of Production Research*, 32, 1615-1635.

Uzsoy, R., C.Y. Lee & L.A. Martin-Vega (1992). A review of production planning and scheduling models in the semiconductor industry Part I: System characteristics, performance evaluation and production planning. *IIE Transactions*, 24, 47-60.

Uzsoy, R. & Y. Yang (1997). Minimizing total weighted completion time on a single batch processing machine. *Production and Operations Management*, 6(1), 57-73.

Wang, C.S. & R. Uzsoy (2002). A genetic algorithm to minimize maximize lateness on a batch processing machine. *Computers & Operations Research*, 29, 1621-1640.

THE STUDY ON FACTORS AFFECTING MOBILE MULTIMEDIA TRAINING

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ABSTRACT

The recent development of information and communication technology in general and the consolidation of these technologies and multimedia technology in particular have brought enormous changes in education methods in many organizations. Numerous studies about teaching learners by multimedia technology in the education field have been published and those studies reported that the multimedia technology would enhance learning performance more than that of traditional teaching methodology. However, few studies about direct investigation on the effectiveness of multimedia technology on learning are found in the corporate training sector. Only a few studies around the effectiveness of multimedia technology in corporate training are found worldwide. In this regard, the major objective of the study is to investigate which factors affect the learner's performance most in multimedia training in business organizations when learners are allowed to have access to the multimedia contents and instructors via mobile devices.

The result of the study will help companies enhance their training outcomes by designing better multimedia training materials that can be delivered through mobile devices. Based on the constructivism theory and motivation theory of the education engineering field, a theoretical research model and research hypotheses were developed. Then the study examined a variety of factors in mobile multimedia technology affecting trainee's learning. A total of 517 employees form five conglomerates participated in multimedia technology embedded training which allowed mobile access. The participants replied on survey questionnaires provided after the training sessions. The result of the four regression analyses and other tests indicated that the hypotheses H3-1 (feedback of learning), H4-1 (information sharing), and H4-3 (Quality of information presentation) among others are the most influencing factors to the success of mobile multimedia learning.

INTRODUCTION

What is mobile multimedia learning? The rapid development and growth of Internet broadband Wi-Fi access and the fast increase of smart mobile device usage make various types of multimedia training materials ubiquitously available through various types of multimedia training systems. Trainees holding smart mobile devices have access to the sophisticated multimedia learning materials anytime wherever they go. The recent advancement and great proliferation of smart mobile devices in the world have paved the way of sharing and accessing multimedia training contents taught in a physical place in different time and place from the time and place of learning offered. The mobile devices are grown up to 'smart' instruments having high performance in terms of memory size, processing speed, and communication capability.

Thanks to the advancement, various types of multimedia contents including audio and video could be accessed by or delivered to mobile devices, such as smart phones, tablets, and personal digital assistants (PDAs). The learning contents could be accessed by individual learners' mobile devices through wireless communication network.

The recent development of information and communication technology in general and the consolidation of these technologies and multimedia technology in particular have brought enormous changes in education methods in many organizations. Numerous studies about teaching trainees by multimedia technology in the education field have been published and those studies reported that the multimedia technology would enhance learning performance more than that of traditional teaching methodology. However, few studies about direct investigation on the effectiveness of multimedia technology on learning are found in the corporate training sector. There are not many studies around the effectiveness of multimedia technology in corporate training (Orrr, Golas, and Yao, 1993; Bielenberg, Carpenter-Smith, 1997; McDonald, 2004). A few studies on mobile learning found in the world (Motiwalla, 2007; Vavoula and Sharples, 2009; Frohberg, Goth, and Schwabe, 2009; Demirbilek, 2010). Only a few studies on multimedia education in a mobile learning environment found (Giza, 2014; Moldovan, Ghergulescu, and Muntean, 2014).

In this regard, the major objective of the study is to investigate which factors affect the trainees' learning performance in business organizations when the training is delivered by the mobile multimedia technology. Then the paper would like to provide companies ways to enhance their training outcomes by designing better training materials with multimedia and mobile technology. Based on the constructivism theory and motivation theory of the education engineering field, a theoretical research model and research hypotheses were developed. Then the study examined a variety of factors in mobile multimedia training, which affect trainees' learning performance.

LITERATURE REVIEW

Multimedia Learning

Multimedia technology based on information and communication technology (ICT) greatly changed the learning system in corporations (Angelides and Demosthenous, 1996). It maximized the effect of learning of employee trainings by providing various media to the trainers and learners such as video, audio, interaction, and easy access to information (Dustdar and Angelides, 1997). Computer aided education, intelligent education, and multimedia embedded learning have been studied for a long time in the education field (Galbreath, 1994). Many frameworks for integrating multimedia technology in classrooms have been suggested and they provided educators with various components of multimedia technology to enhance their classroom activities. Many examples of utilizing multimedia technology in learning were shown to the educators and were useful to guide educators in the fast changing multimedia education world where technology and tools were changing quickly. Educators are constantly upgrading their skills, tools, and technology to cope with recent development in multimedia technology (Giza, 2014). Many researches classified multimedia contents into several categories to help

educators navigate relevant multimedia contents easily through different tools of hyperlinks. These studies aided educators to provide learners better ways to study multimedia contents in a fast development of new technologies, tools, and multimedia educational contents (Moldovan, Ghergulescu, and Muntean, 2014).

Mobile Learning

"Mobile learning is an ongoing learning landscape and education mode in which users can use mobile communication terminals to assist them to learn (Xia, Asabere, Ahmed, Li, and Kong, 2013)." The mobility is the key feature of the mobile learning. Learners in distance can access the learning materials in their moving mode and from any location where wired connection is not provided. The mobile learning eliminates the connection problems in traditional online learning or e-learning and extends the reach of the online multimedia training into much wider landscape. The mobile learning provides benefit to both educators and e-learners at the same time, by allowing e-leaners authority and freedom on their learning methods and pace, and allowing educators flexibility and controls in their e-course management (Motiwalla, 2007).

Recent developments of mobile computing technologies among the Information and Communication Technology (ICT) helped educators utilize multimedia learning contents and connect e-learners into their multimedia materials (Frohberg, Göth, and Schwabe, 2009; Demirbilek, 2010). The advancement in mobile devices that strengthen computing functions provided e-learners ability to use many features of computing that were once available only in the PCs. It could be possible because most e-learners are proficient in using mobile devices regardless of their operating systems and because developments of wired and wireless broadband connections to networks including Internet, Intranet, and common carrier connections. The development of 3G, 4G, and next generation network technology has contributed educators to utilize mobile technology in their online education (Vavoula and Sharples, 2009).

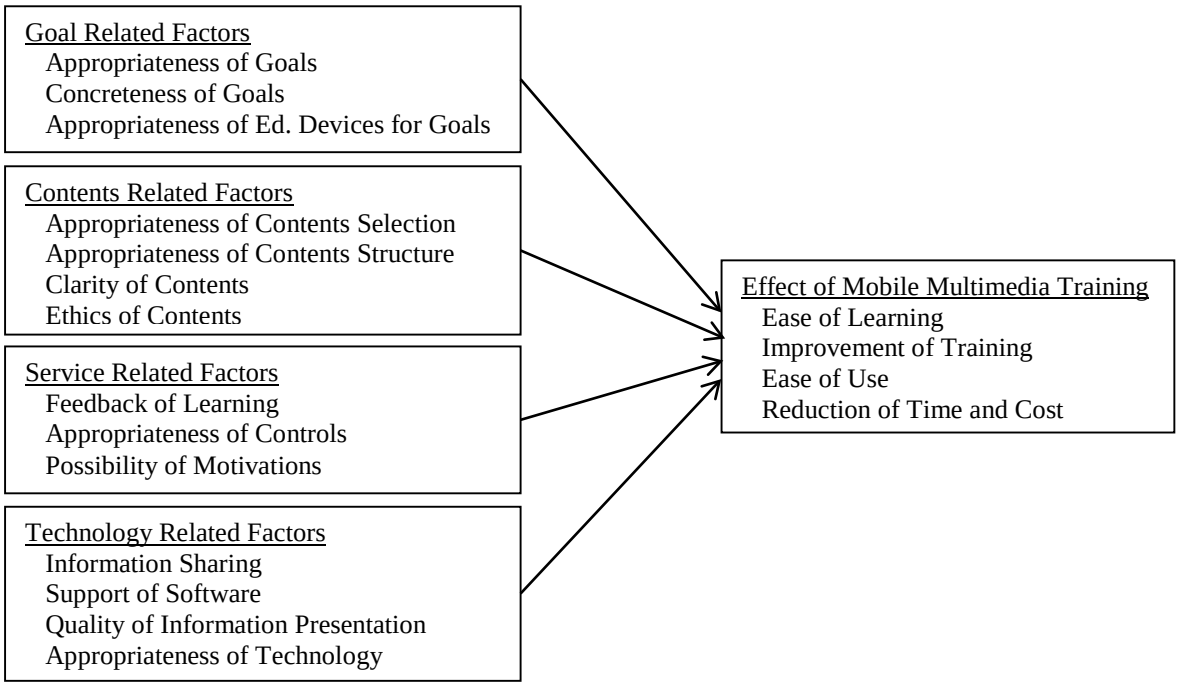
Mobile learning makes e-learners overcome the weaknesses of desktop computer based distance learning by mobility characteristic of mobile devices. Mobility allows e-learners to have location control and easy interactivity in their learning. E-learners can access learning materials provided by instructors from any place, can have communication with other e-learners at a remote location, and can ask questions to instructors from almost everywhere although the wired connection is not available. Further advancement of mobile technologies may even open up the possibilities of collaboration among team members at a remote location by allowing easy sharing of data, easy access to resources, easy communication with other members, and easy discussion among members without wired connection.

RESEARCH MODEL

As the information and communication technology (ICT) advances, the field of training and education has more flexibility and freedom to produce multimedia materials and offers them to mobile computing devices. The importance of using multimedia materials in training and education is validated by many researches in educational field of study (Nardi, 1996). It is also

important to utilize mobile devices in delivering the training materials and in allowing e-learners' access to the learning contents to produce better learning environment. The two trends of providing multimedia learning materials and allowing e-learners access to the learning contents via mobile computing devices will lead a significant change in a corporation training effort. The ubiquitous characteristics of personal mobile devices play an important role in driving mobile multimedia learning in the next decades (Havinga and Smit, 2002). Keller (1984) suggested the motivation theory in education in that ARCS, attention, relevance, confidence, and satisfaction, determines the motivation and intention to use multimedia education materials. In the education field of study, Keller and Suzuki (1988) used ARCS to design lectures and to improve user interest and curiosity in education through computers, which maximizes the effect of learning.

Figure1. Research Model



The studies on multimedia materials deal with contents of multimedia learning, teaching strategy (controls of learning, feedback, and screen design), usage aspect of multimedia materials (time to learn program, program loading time), cost and benefit of multimedia education, and technical support in multimedia education. The research model of this paper is based on the previous studies in the multimedia education field. It is also based on the characteristics of multimedia information systems (Resnick, 1990; Roschelle, 1992; Nardi, 1996; Webster and Ho, 1997), motivation theory applied in various educational devices (Keller, 1984; Keller and Suzuki, 1988), the effects of multimedia information systems (Dustdar and Angelides, 1997; Sharda, 1996), and technology related factors such as information sharing, support of software, quality of information presentation, and appropriateness of technology suggested and used in many mobile and multimedia learning studies (Havinga and Smit, 2002; Motiwalla, 2007; Vavoula and

Sharples, 2009; Wang, Zhang, Chang, and Xu, 2014). The research model includes goals related factors, contents related factors, service related factors, and technology related factors as independent variables. The variable factor is the effect of mobile multimedia training. The model proposed in the study is shown in Figure 1.

Goal Related Factors

A few previous research in education fields suggested that the goal of multimedia education is to accomplish training objectives, utilize appropriate training devices and programs, and offer prerequisite courses (Keller, 1987a; Sharp, 1996) by multiple modes of media. Another study in multimedia education suggested that the multimedia education helps to achieve easy knowledge transfer, support easy learning, and to accomplish concrete foals (Howell and Silvey, 1996). Based on these studies, this study built a set of hypotheses.

H1-1: The appropriateness of goals affects the effect of mobile multimedia training.

H1-2: The concreteness of goals affects the effect of mobile multimedia training.

H1-3: The appropriateness of training devices affects the effect of mobile multimedia training.

Contents Related Factors

Many previous researches suggested that content related factors affect the effect of multimedia education. The content related factors included the selection of content, the ethics of content, the clarity of content, and the content structure (von Glasersfeld, 1989; Hlynka and Belland, 1993; Sharp, 1996). Thus, this study included the content factors to see the effect of these factors on mobile multimedia training.

H2-1: The appropriateness of content selection affects the effect of mobile multimedia training.

H2-2: The appropriateness of content structure affects the effect of mobile multimedia training.

H2-3: The clarity of content affects the effect of mobile multimedia training.

H2-4: The ethics of content affects the effect of mobile multimedia training.

Service Related Factors

The previous studies suggested that the level of motivation, feedback, and control on the learning materials in multimedia education were important in successful multimedia education (Keller, 1987b; Keller and Suzuki, 1988). Based on these suggestions, this study set the following hypotheses.

H3-1. The level of feedback of learning affects the effect of mobile multimedia training.

H3-2: The appropriateness of control affects the effect of mobile multimedia training.

H3-3: The level of motivation on the learning affects the effect of mobile multimedia training.

Technology related factors

The studies done before suggested that the technology related factors such as the easiness of information sharing by technology, how much the learners get software support, quality of information presentation in terms of visualization and clearness of contents also important in multimedia learning. Thus the study included these factors in the hypotheses.

H4-1: The easiness of information sharing affects the effect of mobile multimedia training.

H4-2: The support of software affects the effect of mobile multimedia training.

H4-3: The quality of presentation affects the effect of mobile multimedia training.

H4-4: The appropriateness of technology affects the effect of mobile multimedia training.

Using these hypotheses, the analyses have been done to see the effectiveness of mobile multimedia training.

RESEARCH METHOD

The paper analyzed a set of surveyed data from companies that provided specialized multimedia training in sites and allowed learners to access the contents and instructors via mobile devices. The target organization was the human resources department of large corporations. In the organizations, the multimedia training materials included text, audio, graphic, video, and animation. Among them, for the communication speed to the mobile devices, large video files were suggested to utilize limitedly. Instead, small video clips were recommended to use in the multimedia learning contents. The organizations had multimedia training rooms that is connected by LAN to share the contents through wired networks and is connected by 3G and 4G wireless connections to allow employees to have access the training contents through mobile devices. This paper focused on the trainees'' perception on their training experience through multimedia and mobile technology.

Eight hundred and thirty (830) questionnaires are distributed to the directors of the human resources departments of the large business organizations in S. Korea and the questionnaires were distributed to the employees who participated in various types of trainings that were offered through their multimedia training rooms and allowed trainees to access the contents they learned and instructors through mobile devices for their further studies. The completed questionnaires were faxed, mailed, and emailed to us to retrieve data in the surveys. Out of the eight hundred and thirty questionnaires distributed, five hundred and forty three responses were collected. Five hundred and seventeen (517) questionnaires were finally included in the analysis after twenty six questionnaires were excluded as they contain inappropriate responses for our analysis. The response rate was 65% and is high enough for this empirical

study. The response on the questionnaires was encouraged by the instructors who conducted the trainings. The respondents held a variety of positions and careers, but most of them were assistant managers and managers (85%) of the companies, although the largest population in the survey was assistant managers (40.6%). The largest portion of participants held bachelor degrees (47.9%), and the highest percentage of them had their work experience for six to ten years (42.7%). The detailed demographic statistics of respondents are in the Table 1, 2, and 3.

Table 1
PARTICIPANTS' JOB POSITIONS

	Entry Level	Operational Manager	Middle Manager	Divisional Manager	Top Manager	Total
n	117	210	112	55	23	517
Percentage	22.7	40.6	21.7	10.6	4.4	100

Table 2
PARTICIPANTS' EDUCATION

	High School	Associate	Bachelor	Master	PhD	Total
n	92	113	247	63	12	517
Percentage	17.8	21.8	47.9	12.2	2.3	100

Table 3
PARTICIPANTS' WORK EXPERIENCE (YEARS)

	Less than 5	6-10	11-15	16-20	More than 21	Total
n	85	221	151	53	17	517
Percentage	16.4	42.7	29.2	10.3	3.4	100

RESULT

Measurement Properties of Variables

Validity and reliability tests were conducted for all the variables. For the validity, both content and construct validity were tested. The representativeness or sampling adequacy of the content of the measures was pretested by the selected industry practitioners and field experts, and guaranteed by the measures used by previous studies. Construct validity was assessed using convergent and discriminant validity. Convergent validity that sees all the items are measuring a construct cluster together and are forming a single construct was good enough for the items to converge into cluster and form a single construct. Discriminant validity that refers to the degree to which a concept differs from other concepts was good enough to be seen that each concept was different from others. The validity was tested by principal component factor analyses as shown in Table4 and Table5. Separate domain factor analyses were performed with items belonging to all the four factors and the dependent variable. The three commonly employed decision rules (minimum Eigen value of 1, simplicity of structure, and minimum factor loading of 0.5) to identify factors were used. The principal component factor analyses with varimax

rotation produced appropriate number of items in each factor. The coefficient alphas that explain reliability of all the scales exhibited sufficient reliability as they exceed 0.7. The factor analyses and reliabilities showed strong evidence for the construct validity of variables.

Table 4
PRINCIPAL COMPONENT FACTOR ANALYSIS FOR INDEPENDENT VARIABLES

Class	Variable	Measure	Factor Loading	Alpha	Variance Extracted
Goal Related Factors	Appropriateness of Goals	GAG1	0.724	0.765	71.1
		GAG2	0.832		
	Concreteness of Goals	GCG1	0.835	0.825	
		GCG2	0.768		
		GCG3	0.826		
	Appropriateness of Ed. Devices	GAED1	0.817	0.716	
		GAED2	0.673		
Content Related Factors	Appropriateness of Contents	CAC1	0.848	0.719	74.9
		CAC2	0.841		
		CAC3	0.748		
	Appropriateness of Content Structure	CACS1	0.765	0.765	
		CACS2	0.770		
	Clarity of Contents	CCC1	0.875	0.849	
		CCC2	0.873		
		CCC3	0.834		
	Ethics of Contents	CEC1	0.748	0.752	
		CEC2	0.712		
Service Related Factors	Feedback of Learning	SFL1	0.879	0.895	71.3
		SFL2	0.859		
		SFL3	0.787		
	Appropriateness of Contents	SAC1	0.824	0.773	
		SAC2	0.781		
		SAC3	0.668		
	Possibility of Motivation	SPM1	0.863	0.891	
		SPM2	0.838		
		SPM3	0.763		
Technology Related Factors	Information Sharing	TIS1	0.825	0.764	72.1
		TIS2	0.845		
	Support of Software	TSS1	0.812	0.673	
		TSS2	0.698		
	Quality of Information Presentation	TQIP1	0.852	0.769	
		TQIP2	0.836		
		TQIP3	0.877		
	Appropriateness of Technology	TAT1	0.865	0.789	
		TAT2	0.793		

Table 5
PRINCIPAL COMPONENT FACTOR ANALYSIS FOR DEPENDENT VARIABLES

Class	Variable	Measure	Factor Loading	Alpha	Variance Extracted
Effect of Mobile Multimedia Training	Easy of Learning	EEL1	0.765	0.765	77.3
		EEL2	0.886		
		EEL3	0.841		
		EEL4	0.874		
	Improvement of Education	EIE1	0.831	0.687	
		EIE 2	0.783		
		EIE 3	0.694		
	Ease of Use	EEU1	0.781	0.786	
		EEU2	0.862		
		EEU3	0.839		
		EEU4	0.779		
		EEU5	0.691		
	Reduction of Time and Cost	ERTC1	0.889	0.871	
		ERTC2	0.873		
		ERTC3	0.859		

Test of Hypotheses

Multiple regression analysis that is the most common approach for testing the effect of independent variables on dependent variables was used to see how each of independent variables affects each of the dependent variables. The effect of each independent variable was examined while controlling the effect of the other independent variables through multiple regression analysis. All the regression equations turned out to have overall significant F ratios. This means that the collective explanatory power of the independent variables to the dependent variables was statistically significant. The result of the multiple regression analyses is shown in Table 6.

The result of the four regression analyses and other tests indicated that the hypothesis H3-1 (feedback of learning), H4-1 (information sharing), and H4-3 (Quality of information presentation) were fully accepted as shown in Table7. This indicates that the multimedia learning was the most efficient in feedback of learning when it was delivered through mobile devices. In other words, the trainees saw that the extent of feedback in response to the multimedia learning activities to provide appropriate training information was the most prominent benefit of mobile multimedia training. Information sharing for their learning could happen more easily through mobile devices that could be carried by the trainees anytime wherever they go. This information sharing promoted learners' ease of learning in their training, overall learning improvement, ease of use of the multimedia materials, and the reduction of learning time and overall learning cost. The quality of information presentation also affected the learners' understanding of multimedia contents delivered via mobile devices. Especially, the visual pictures, clearness of the pictures and letters, and clearness of the multimedia data enhanced trainees' learning a lot. In addition to those, mobile delivery of multimedia contents increased learners' memory of contents, extended learners' interest, and also improved instructor's instant responses to the learners. The mobile

Table 6
REGRESSION ANALYSES RESULTS

Independent Variables	Dependent Variables							
	Ease of Learning		Improvement of Education		Ease of Use		Reduction of Time and Cost	
	t Value	Sig. T	t Value	Sig. T	t Value	Sig. T	t Value	Sig. T
Appropriateness of Goals	0.859	0.242	0.498	0.492	0.869	0.357	1.779	0.071
Concreteness of Goals	3.279	0.003*	-0.8901	0.289	1.123	0.142	0.985	0.239
Appropriateness of Ed. Devices	-0.242	0.692	0.879	0.310	2.254	0.032^	0.491	0.634
Appropriateness of Contents	2.041	0.051^	0.286	0.601	2.285	0.029^	1.742	0.079
Appropriateness of Content Structure	-0.065	0.793	0.367	0.559	0.972	0.204	2.858	0.017^
Clarity of Contents	2.268	0.029^	3.312	0.005*	3.219	0.002*	1.019	0.221
Ethics of Contents	1.740	0.081	1.301	0.079	-1.057	0.176	-1.392	0.159
Feedback of Learning	5.639	0.000*	2.284	0.029^	4.792	0.000*	4.210	0.000*
Appropriateness of Contents	2.031	0.041^	1.193	0.086	0.715	0.397	1.121	0.210
Possibility of Motivation	4.375	0.000*	2.167	0.037^	0.501	0.612	3.179	0.005*
Information Sharing	2.416	0.029^	2.209	0.041^	3.289	0.003*	3.217	0.004*
Support of Software	1.540	0.148	1.045	0.122	0.891	0.371	0.934	0.367
Quality of Information Presentation	2.719	0.019^	-2.891	0.031^	2.269	0.021^	4.064	0.000*
Appropriateness of Technology	0.698	0.272	0.801	0.401	0.897	0.381	2.792	0.029^

Table 7
RESULT OF HYPOTHESES TESTS

Factors	**Variables**	**Test Results**
Goals related Factors	Appropriateness of Goals	H1-1 Reject
	Concreteness of Goals	H4-4 Partially accept
	Appropriateness of Training Devices	H4-4 Partially accept
Contents related Factors	Appropriateness of Contents	H4-4 Partially accept
	Appropriateness of Contents Structure	H4-4 Partially accept
	Clarity of Contents	H4-4 Partially accept
	Ethics of Contents	H2-4 Reject
Service related Factors	Feedback of Learning	H3-1 Accept
	Appropriateness of Controls	H4-4 Partially accept
	Possibility of Motivation	H4-4 Partially accept
Technology related Factors	Information Sharing	H4-1 Accept
	Support of Software	H4-2 Reject
	Quality of Information Presentation	H4-3 Accept
	Appropriateness of Technology	H4-4 Partially accept

delivery also reduced training time and cost, especially the cost of learning outside of physical learning place.

All the other hypotheses after three fully accepted hypotheses are partially accepted except three rejected hypotheses, appropriateness of goals, ethics of contents, and support of software. This indicates that all the other variables except the three fully accepted and three rejected ones affect the learning effectiveness partially in terms of ease of learning, improvement of education, ease of use, and reduction of time and cost.

COLCLUSION

By recent development of information and communication technology (ICT), multimedia training in any corporation can be enhanced by utilizing mobile computing and delivering the multimedia contents via advanced mobile devices. The result of the study indicated that the trainees' learning could be improved by providing direct feedback and encouraging various feedbacks from learners to the instructors and to the other learners via mobile devices. Another benefit of utilizing mobile devices for delivery of and access to multimedia contents was that the delivered contents could be more easily corrected by providing the way of easy communication and feedback through smart mobile devices. By the mobile delivery, learners could share information more easily. Trainees could also have repetitive learning although they were not physically in the training site. Information sharing on the multimedia contents that trainees learned could happen more easily through mobile devices that could be carried by the trainees anytime and anywhere. This information sharing happened via mobile devices helped learners study the multimedia contents that were taught by instructors in different time and different place. The quality of information presentation affected the learners' understanding of multimedia contents a lot when they were allowed to access by the learners via mobile devices. In addition to improving learners' understanding, access to multimedia contents via mobile devices enhanced learners' memory of contents, extended learners' interest, and also improved instructor's instant response to the learners. The mobile access to the multimedia contents also reduced training time and overall training cost, especially the cost of learning outside of physical learning site.

REFERENCES

Angelides, M.C. & A. Demosthenous (1996). *Towards Multimedia Based Training Systems*, The Impact of Information Technology: From Practice to Curriculum, 101-107.

Bielenberg, D.R. & T. Carpenter-Smith (1997). Efficacy of story in multimedia training. *Journal of Network and Computer Applications*, 20(2), 151-159.

Demirbilek, M. (2010). Investigating attitudes of adult educators towards educational mobile media and games in eight European countries. *J. Inf. Technol. Educ.*, 9, 235-247.

Dustdar, S. & M.S. Angelides (1997). Organizational impacts of multimedia information systems. *Journal of Information Technology*, 12, 33-43.

Frohberg, D.C. Göth, & G. Schwabe (2009). Mobile learning projects: A critical analysis of the state-of-the-art. *Journal of Computer Assisted Learning*, 25(4), 307-331.

Galbreath, J. (1994). Multimedia education: because it's there? *TECH TRENDS*, 17-20.

Giza, Brian (2014). Tools, tasks, and strategies: multimedia education in a mobile world. *Society for Information Technology & Teacher Education International Conference*, 2014(1), 1490-1495.

Havinga, P. & G. Smit (2002). *Mobile Multimedia Systems.* Springer US.

Howell, J.J. & L.O. Silvey (1996). *Interactive Multimedia Training Systems*, The ASTD Training and Development Handbook: A Guide to Human Resource Development, 4th Ed., New York, NY: McGraw-Hill, 534-553.

Hynka, D. & J. Belland (1993). *Paradigms Regained: The Uses of Illuminative, Semiotic, and Post-modern Criticism as Modes of Inquiry in Educational Technology*, Englewoods, NJ: Educational Technology Publications.

Keller, J.M. (1984). The use of the ARCS model of motivation in teacher training. *Aspects of Educational Technology*, 17, Staff Development and Career Updating, London, Kogan Page.

Keller, J.M. (1987a). Development and use of the ARCS model of instructional design. *Journal of Instructional Development*. 10(3), 2-10.

Keller, J.M. (1987b). The systematic process of motivational design. *Performance and Instruction*, 26(9), 1-8.

Keller, J.M. & K. Suzuki (1988). *Application of the ARCS model to courseware design*. New York, LEA.

McDonald, D.S. (2004) The influence of multimedia training on users' attitudes: lessons learned. *Computers & Education*, 42(2), 195-214.

Moldovan, A., I. Ghergulescu, & C. Muntean (2014). Learning assessment for different categories of educational multimedia clips in a mobile learning environment. *Society for Information Technology & Teacher Education International Conference*, 2014(1), 1687-1692.

Motiwalla, L.F. (2007, Nov). Mobile learning: A framework and evaluation. *Computers & Education*, 49(3), 581-596.

Nardi, B.A. (1996). *Context and consciousness: Activity theory and human-computer interaction*. Cambridge, Massachusetts, MIT Press.

Orrr, K.L, K.C., Golas, & K. Yao (1993). Storyboard development for interactive multimedia training. *The Interservice/Industry Training, Simulation & Education Conference (I/ITSEC)*, 1993(1), National Training Systems Association.

Resnick, L.B. (1990). *Literacy in school and out*. Daedalus, spring, 169-185.

Roschelle, J. (1992). Learning by collaborating: Convergent conceptual change. *Journal of the Learning Science*, 2, 235-276.

Sharda, N.K. (1999). *Multimedia information networking*. New Jersey, Prentice Hall.

Sharp, V. (1996). *Computer education for teacher*. Brown and Benchmark.

Vavoula, G. & M. Sharples (2009). Meeting the challenges in evaluating mobile learning: A 3-level evaluation framework. *International Journal of Mobile Blended Learning*, 1(2), 54-75.

von Glasersfeld, E. (1989). Cognition, construction of knowledge and teaching. *Synthesis*, 80, 121-140.

Wang, Z., Z. Zhang, Y. Chang, & M. Xu (2014). An approach to mobile multimedia digital rights management based on android. *Genetic and Evolutionary Computing*, Springer International Publishing, 239-246.

Webster, J. & H. Ho (1997, Spring). Audience engagement in multimedia presentations. *The DATA BASE Advances in Information Systems*, 28(2), 63-76.

Xia, F.N., Y. Asabere, A.M. Ahmed, J. Li, & X. Kong (2013). Mobile multimedia recommendation in smart communities: a survey. *IEEE Access*, 1(1), 817-827.

ROAD WARRIORS AND INFORMATION SYSTEMS SECURITY: RISKS AND RECOMMENDATIONS

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ABSTRACT

Information systems are threatened by "road warriors" and other employees whose computer and other electronic devices are used outside the organization. Devices can be lost, compromised, or misused; communications can be intercepted and organizational systems can be penetrated, especially when the compromised devices are brought back inside the organization. The increasing use of "cloud computing" and "BYOD" (Bring your own device) add to those risks. Specific threats are discussed along with recommendations for reducing the likelihood of problems.

INTRODUCTION

It is widely known that information systems are an important part of most organizations and an essential part of many. It is also widely known that systems connected to the Internet are at risk of penetration by hackers, including competitors, criminals, foreign governments, and others—see Fisher, Tinsley, & Strader (2010) for a discussion of the threats and recommended non-technical precautions (technical precautions are beyond the scope of this paper and are best left to information security professionals). Unfortunately, even organizations with state-of-the-art security installed on their information systems are at risk from their own employees, particularly "road warriors" and other employees whose computers and other electronic devices are used outside the protection of the organization's security systems. The risk is especially great when systems are accessed from outside the organization as well as when employees use devices outside the organization--exposing them to the risk of malware--and subsequently bring them back inside the organization's system. The situation is made worse if employees violate company information security policies. Doing so is an especially great temptation for road warriors (D'Arcy & Devaraj, 2012), since higher security often requires increased time and effort to use devices and systems.

Hackers and malware have long been associated with networks and desktop or laptop computers. Unfortunately, the surging popularity of smartphones and tablet computers has captured the hackers' attention. Mobile threats are growing rapidly, with the fastest growth in attacks on Google's Android devices (Drew, 2012). One reason revealed in a recent study is that many Android devices have known and longstanding vulnerabilities that have not been patched (repaired by update). Older devices are at an especially great risk because manufacturers and/or phone carriers stop sending out updates too soon (Constantin, 2012). Once a device (whether computer, phone, etc.) is compromised, both the data on that device and the systems the device can access are at risk.

One current trend that adds risk is the increased reliance on the Internet through "cloud computing." Although that term has many definitions (Geelan, 2009), this study focuses on the

situation in which application software and/or its associated data are "in the cloud," i.e., on the Internet, physically away from the using person or organization. This results in both a loss of control and an increased exposure to Internet risks. "BYOD" (bring your own device) is another trend that adds risk. As reported by Burt (2011), some employees prefer to work with a smartphone, tablet, or other device that they already own and are comfortable with using. Businesses are also attracted to this paradigm because it puts the equipment purchase burden on the employee. The problem is how to maintain security on devices that the organization does not control. Older devices (especially older Android devices) are particularly problematic, since security updates may be unavailable (Constantin, 2012). The following sections address the threats posed by road warriors and other employees who use their device(s) outside the organization. Recommendations for reducing the risk of harm from the various threats are also provided.

RISKS POSED BY ROAD WARRIORS

Nearly everyone uses computers and/or other electronic devices in their work. Sometimes, a device is physically taken outside the organization to facilitate the employee's work while travelling or at home. The term "road warrior" is often applied to employees who spend an especially large percentage of their work time travelling. Such employees have in fact long been early adopters of information technology. From the time of the first generation "portable" computers to the latest and greatest smartphone of today, the traveling business person has used technology to keep in touch with colleagues and clients. Many road warriors also utilize their business devices for personal purposes, such as to keep in touch with family and friends while away from home. Multiple devices are becoming the norm, with many people carrying a smartphone (or two), a tablet computer, and/or a laptop computer. A recent study of over 6000 guests by Four Points Sheraton Hotel chain found that over half of business guests carried three or four devices with them, with a smartphone being the most popular, followed by tablets and then laptops (Ragan, 2012).

If a device contains sensitive information (which it often would), a major concern is that information on or transmitted to or from the device might fall into the wrong hands (competitors, thieves, news organizations, foreign governments, etc.). This can happen accidentally, such as when the employee leaves a cell phone in a cab or a tablet computer in the airport security screening area. That happens often: in 2011, over 8,000 mobile devices were left behind at the seven largest airports in the U.S. (Ragan, 2012). A device might also be stolen from an employee's vehicle, motel room, or home, and the thief might be looking for more than just a few dollars at the nearest pawn shop. Further, it might not be necessary to steal a device to compromise data. A data thief might merely *access* the device while it is left unattended. And, if a device is used for non-secure communications, electronic eavesdroppers may obtain sensitive information. Tablets are of special concern in this regard, since it is more likely that the road warrior is accessing confidential information than if they are just checking their email on a smartphone (Cox, 2012). Another risk is that information could be displayed on screen under circumstances in which it can be seen by unapproved persons (e.g., over-the-shoulder).

Of necessity, road warriors often use their device(s) to connect to the Internet from hotels, airports, and other non-secure locations. Several problems can result: (1) If the location's Internet connection is not secure, communications may be intercepted; (2) Hackers can setup "ad hoc" networks that are similar to those of a legitimate location's network and fool the traveler

into accessing the bogus network; and (3) the ability of a device to setup a wireless "hot spot" may be convenient but may allow other less secure devices to access it. Regardless of where a device is used, infection by malware (including spyware) may occur if the user is careless about web sites visited, software installed, e-mail attachments opened, etc. Even for careful users, part of the problem with any device that connects to the Internet is the risk that a hacker will exploit an un-patched vulnerability (Fisher et al., 2010; Riley & Vance, 2011).

Riley & Vance (2011) and Panton et al. (2014) report that "zero day" exploits (those that no one but the creator knows about) are bought and sold, so even users with up-to-date devices are at risk. A hacker that gains control of a device can plant a "keystroke logger" program on it to extract passwords, then take control of the device, extract any data or documents on it, and use it to log into systems the user accesses. Note that this type of attack may be successful even if the organization's system requires secure access (e.g., virtual private network (VPN)), since the hacker can probably do anything with the device that the user could do.

Another danger from malware-infected devices is that a user could accidentally or intentionally bring the infected device back into the organization and connect to a sensitive system. Often, protection of sensitive systems is focused on the Internet connection and firewall, so malware on an internally-connected device might easily slip in. Even a system not connected to the Internet at all could be compromised in this manner. Stealthy malware might just collect information from such a system, then await an opportunity to transmit it to the hacker when the device is again removed from the organization.

If an employee collects data or creates documents while travelling, damage to or loss of the device could result in loss of irreplaceable information. The use of cloud-based applications or back-up storage may help but then bring its own problems. Persons traveling between countries may face (usually temporarily) device confiscation and snooping by government employees. U.S. Customs officials have the authority and sometimes seize devices being brought into the U.S. including those owned by U.S. citizens; other countries operate with similar procedures (Bector, 2009). Further, a device "inspected" by a government--or even by an organization--could be returned with malware installed. Just using a device in a non-secure area can result in data being compromised. Connecting to the Internet at a customer's site could allow their system to penetrate the road warrior's system, possibly compromising product costs or other sensitive information that a sales person needs but that the company does not want the customer to see. Nakashima and Wan (2011) report that problems are particularly serious in China where smartphone contents can be downloaded in seconds, and networks (and the Internet) are widely monitored by government agents. They also report that malware has been remotely installed in smartphones and later used to infect servers in the U.S.

Eddy (2010) reports a disturbing trend among road warriors: use of business and/or personal devices for personal purposes while travelling on business. The author reports that younger workers are especially likely to update social network accounts, "tweet" about their travels, and/or randomly surf the web. This activity is problematic in at least two different ways: (1) The traveler's location and activities can be identified, which could let a client or supplier know where the person has been thus identifying potential clients or new business locations and (2) Social networks are common targets (McMillan, 2011) since few users ever read the end license agreements, and malware can easily be installed. Another issue with accessing web sites other than the organization's systems is that many sites store "cookies" that can contain sensitive information, and other sites can potentially access that information. Lanois (2011) reports a particularly troubling related issue: cookies based on the Adobe Flash player are not controlled

by the user's browser privacy settings, and flash cookies can even reconstruct cookies that the user has deleted.

CLOUD COMPUTING ISSUES

The use of cloud computing is exploding. A 2011 survey showed that 45 percent of multinational corporations used some form of cloud computing services (up from 24 percent in 2010), and many more were planning to adopt cloud computing over the next five years (Lanois, 2011). More recent surveys indicate continuation of the trend (Cohen, 2013). A major attraction of cloud computing is that the organization does not have to maintain the hardware and software that it uses, thereby saving time and money. And, because systems are accessed over the Internet, employees can access them from anywhere. Data security for a road warrior can actually be better than the traditional method of carrying data and documents on a laptop: loss or damage of a device that accesses a cloud system does not necessarily cause a serious problem, since the data and documents are not located on the device (Blyth, 2011). However, cloud computing usually requires that the employee connect to the Internet to do meaningful work. Doing so is always risky and sometimes (especially at hotels/motels and other non-secure hotspots) is very risky (Fisher et al., 2010). Loss of a device that is not secure (e.g., no access password, an easily-defeated password, or unencrypted storage) could allow the thief to get into cloud-based systems just as easily as getting into systems located on the device if the cloud-based systems are set up for automatic login or have saved passwords.

When a road warrior uses a cloud-based system, he or she is logging into a system that is not controlled by the company. The cloud provider (particularly free services) may have less-than-optimal security and/or may collect and distribute information about users. Problematic practices may be disclosed only in the fine print of a hard-to-read end user license agreement (EULA). The provider's employees have no loyalty to the road warrior's organization and may be tempted to profit at their expense. The reduction of company resources required to set up and run cloud-based systems may be at least partly offset by an increase in company resources needed to ensure that the provider's security is adequate (and possibly more resources to fix issues if the security is breached). If the road warrior depends on a cloud site to do a presentation or to access information needed for a meeting with clients or customers, there is the risk that the site or the local Internet connection could be very slow or even fail completely. For example, the Prezi presentation site became virtually unusable for several days in early November, 2012 ("Website Temporarily Down," 2012).

BRING YOUR OWN DEVICE (BYOD) ISSUES

One of the alarming trends for IT security professionals is the popularity of BYOD (Bring Your Own Device). Some recent reports indicate that BYOD is a rapidly growing trend that is here to stay (Rhodes, 2012). Supporting that theory, Burt (2011) reported a study showing that over 40% of the devices used by employees in 2011 were owned by the employees (not the company), up 10% over the previous year. Others (Cox, 2012) find that, although organizational use of tablet devices like iPads is growing rapidly, some firms are choosing to deploy only company-owned devices in order to maintain greater control. The problem is that mobile devices are risky under ideal conditions, and having to control multiple brands and models of non-owned devices—each of which normally requires a different installation of basic anti-virus, firewalls,

VPN, and other security software—makes the situation much more difficult for the organization's IT staff (Rhodes, 2012). BYOD is particularly troubling for accounting firms and others that store confidential customer data on their systems. If an employee downloads confidential data to a personal device and that device is subsequently lost, stolen, or compromised, the firm could face liability and regulatory consequences in addition to serious reputational damage (Drew, 2012). There are also negatives for the employee as reported by Rhodes (2012). The company will probably require that mobile device management (MDM) software be installed, and that could result in personal files (like pictures of a new baby) being wiped if the device is temporarily misplaced. Note that this could also cause the employee to delay reporting a missing device, thereby adding to the risk that company data or systems could be compromised. Rhodes (2012) also reports that MDM software often logs GPS locations, so employees may be surprised to find that the boss knows where lunch hours are spent. Finally, the employee who uses his or her own device for work is probably going to expect to retain personal usage rights. Failing to read the fine print in a new application or cloud service EULA could expose the user and organization to risk.

RECOMMENDATIONS

The next section of this paper will discuss in detail recommendations on how to deal with specific security issues that arise with road warriors. We will discuss physical and electronic security, tactics to deal with attacks from inside the organization, and travel in risky locations. We will further address strategies for security in cloud computing and BYOD situations followed by a discussion of the importance of multi-factor authentication and VPN (Virtual Private Network) use along with other general security guidelines.

Physical Security

One of the first things a road warrior should do is ensure the physical protection of his or her device(s). Road Warriors (and other technology users) like that newer devices are becoming smaller and lighter in weight, but that makes it easier for a thief to steal or for the device to be misplaced. Suggestions from Piscitello (2012) and Pash (2009) include:

1. If possible, use a security cable on the device.
2. Install "alarm" software that will set off an alarm if the device is moved, unplugged, etc.
3. Link the device to another device easily carried with you, such as Bluetooth key fob attachments. These vary in capabilities ranging from locking down a device when out of range to sounding an alarm. Drew (2012) provides further discussion of the "leashing" software used for this purpose.
4. Require appropriate security at employee residences if devices are kept or used there.

Electronic Security

It is typically not possible to completely eliminate the chances of a device falling into the wrong hands. Consequently, precautions must be taken that will protect the organization's data and systems in case that happens. The following three features are recommended at a minimum, and devices lacking one or more of these should be avoided (Piscitello, 2012; Whitwam, 2012):

1. Set a passcode, boot password, or the equivalent for the device. That is, the device should be completely unusable unless and until the proper passcode is entered. Obviously, the passcode should

be strong, i.e., hard to guess (an Internet search of "strong password" will reveal many sources for advice), and the device should be set to require the passcode after a relatively short idle period. For even stronger protection, use a device with "multi-factor authentication" as described below. Also, more secure devices like the iPad automatically encrypt all data if a passcode is set (Mogull, 2011).

2. Encrypt all sensitive data and documents with a passcode that is different from that for the device. Even if the device is passcode-protected, there is the possibility that the passcode could be guessed or that the device's memory or hard drive could be removed and accessed. Encrypting the data and documents with a different passcode provides a second layer of protection in case the device is penetrated. Encryption is available in most operating systems, in some applications, and from third-party software.
3. Activate remote wiping on each device. Most modern portable devices have the capability of being wiped (erased) remotely in case of loss or theft, but the feature is often turned off by default. Apple iCloud and Google Sync users automatically have this capability ("Find My iPhone," 2014; "Remote Wipe," 2012).

Protect Against Inside Attacks

Another high priority should be protecting the organization's systems from compromised devices. Obviously, systems connected to the Internet should have appropriate security precautions (firewall, etc.) to protect from outside attacks. It is at least as important to have policies in place that protect from inside attacks, especially from devices that have been used outside and brought back inside. Because such a device might have been compromised, it should not be allowed to connect to an internal system unless and until cleared by company security experts. Even a flash drive or CD can contain malware that attempts to install itself when inserted into a computer, so those items should also be inspected carefully before use. In fact, it has been recently reported that USB device code can be hacked in a manner that allows, for example, a flash drive to function as a keyboard to type malicious commands or install malicious software ("BadUSB," 2014). Obviously, that means that all users should avoid connecting unknown USB devices to their computer regardless of where the computer is located.

Travel in Risky Locations

For employees traveling to risky locations (where the risk that a device might be confiscated, compromised, or have communications intercepted is high), it may help to issue a device specifically set up for high security (see other recommendations) and the ability to access only information absolutely necessary for the trip. The authors of this paper have been told that some organizations issue a device with newly-formatted memory before such a trip and re-format the memory upon return. The logic is that use of a device in a high-risk area creates a significant likelihood of malware infection regardless of precautions. This would be especially true if a device were taken out of the user's control, such as for "inspection" by an organization or government. In any case where the device is outside the user's control for any period of time, it would be safest to assume that it has been compromised and act accordingly.

Nakashima & Wan (2011) report that some travelers keep information on flash drives and only access it from off-line computers. Those authors also report that a particular security expert recommends buying a new device before each trip, then never using it again. While a bit extreme, that action would protect against hidden malware that might survive memory reformatting as well as use of the device identifying information to track the user. Other suggestions from those authors include leaving devices behind altogether or removing the batteries from a device when in an especially sensitive situation. The latter tactic has the

advantage of ensuring that no GPS data are produced by the device during the sensitive time frame.

Cloud Computing

Greater control is usually had by *not* using cloud systems. In situations where the advantages of cloud computing outweigh the disadvantages, it makes a lot of sense to look for external validation that the vendor site has state-of-the-art security. As reported by Julisch & Hall (2010), it is good to look for SAS 70 ("SAS 70 Overview," 2012) and/or ISO 27001 ("ISO 27001 Security," 2012) certification. However, Ristov, Gusev, and Kostoska (2012) report that the popular ISO 27001:2005 certification fails to address certain threats and vulnerabilities. Those authors propose extensions to the certification that, if adopted, should lead to higher security in certified cloud providers. Other recommendations for ensuring cloud vendor security are provided by Drew (2012).

One way to have some of the advantages of a cloud system while still retaining control is to use a "private" cloud. That is, the system is set up for and used only by the road warrior's organization, as opposed to the "public" cloud systems that simultaneously serve many customers. As indicated by Schultz (2011), some organizations choose to have both public and private cloud systems depending on the security needs of each.

As noted above, cloud systems suffer from the risk that the Internet or the cloud site could temporarily be very slow or even fail. Consequently, if a road warrior is planning to make a presentation or conduct business that requires access to a cloud-based system, it would be wise to have a "plan 2," i.e., an alternate means of carrying out the tasks. For example, an online presentation can usually be saved to a computer or flash drive, and even a paper copy might be better than nothing. Similarly, data normally accessed via cloud computing might be saved on a device, and transactions could be stored temporarily for entry later. Of course, security appropriate to the value of the data should be used.

BYOD

We agree with Walters (2012) of US-CERT (United States Computer Emergency Readiness Team) and Piscitello (2012) that security is better if personal and business data/systems are kept completely separate. If the firm does decide to embrace BYOD, employees using personally-owned devices should of course be instructed to use the same precautions as for company-owned devices. These additional steps are particularly important for BYOD:

1. Require that each device be set up for security proportional to the value of information stored on, accessed, and/or transmitted by the device, such as lock codes, restricted application access, encryption, etc. (Drew, 2012; Piscitello, 2012).
2. Require that employees sign agreements authorizing remote erasure of their device should it be lost, stolen, or misplaced, and have included in the agreement a timeframe in which the loss must be reported before major penalties kick in for the employee. This is particularly important if the device has access to sensitive organization systems (Drew, 2012).
3. Subject each device to vulnerability scanning to identify common problems (Piscitello, 2012).
4. Require that different passwords be used for personal use (e.g., banking; social networking) and for access to organizational systems.
5. It may be desirable to allow only company-owned (secure) devices to access more sensitive systems.

Multi-Factor Authentication

Devices and systems that contain sensitive information may not be adequately protected by a single password. Even if a password is strong, the possibility exists for it to be seen while being typed or be recorded by keystroke logger malware. Better security is had with "multi-factor authentication," also called "multi-step verification" (previously known as two-factor authentication or verification). Awareness of this process is increasing as both Google and Facebook are offering the service to their users. The best multi-factor authentication systems require the user to present at least two of the following three kinds of authentication ("Multi-factor authentication," 2014):

1. Something the user *knows* (such as a password or PIN).
2. Something the user *has* (such as credit card, USB plug-in device, or specific computer).
3. Something the user *is* (biometric characteristic, e.g., fingerprint, retina pattern, etc.).

An ATM machine, for example, requires both the ATM card and a PIN. Some banks require that a specific device be registered with the server, and additional authentication is required if the user attempts to access the site from an unregistered device. With Gmail and many other sites, the additional authentication is in the form of sending a PIN to the user by a means other than the Internet, such as by cell phone ("About 2-step verification," 2014). Less secure methods (but still better than a single password) often have the user provide an additional piece of information after logging in, such as a PIN or the answer to a security question.

Restrict User Privileges

Because users can accidentally or intentionally take actions that compromise security, steps should be taken to limit their ability to do so. One way is by requiring that employees only access company systems using a computer or other device that implements "least privilege security." Many devices and all major computer operating systems have the ability to create user accounts that are limited in functionality. A separate "administrator" account is used to set user limits and perform functions that are not allowed for users. One typical limitation is on the ability to install software, thereby preventing the user from accidentally or intentionally installing malware or an application that compromises the device's security. Least privilege security is discussed in depth by Smith (2010). Although a bit more complicated than just setting up non-administrator accounts, functions can also be limited on iOS (iPhone; iPad) and Android devices (Bohon, 2011; "Deploying," 2012; "Device Administration," 2014).

Require Use of VPNs or a Travel Router

Communications between the user and organization systems (whether those systems are internal or cloud-based) will be much more secure if via VPN than if by ordinary Internet connections (Walters, 2012). Since the quality of VPN software can vary, the product selected should be consistent with the security needed for the particular system. Some systems connect through the organization's VPN for all Internet access, thereby allowing greater control than if the user connects directly to the Internet. One of the problems with that arrangement is that the organization's VPN must then be high enough capacity for all of the users' Internet needs, which can be a problem with high-bandwidth sites like Netflix and Youtube. Some organizations limit

access to non-essential high-bandwidth sites to preserve system performance under this setup (Neff, 2012). One way to greatly improve the security of hotel/motel and other low-security systems is to connect through a "travel router": a portable device that creates a "private, secure, wireless network with a robust firewall" (Brown, 2014). That is, the travel router connects to the low security Internet access system, creates a secure wireless network for the user(s), and puts a quality firewall between the secure network and the Internet in much the same way that a normal router would.

Motivate Security Policy Compliance

It does not help to have information security policies if employees do not follow them. As reported by Puhakainen and Siponen (2010), training--when done properly--*does* improve employee compliance with security policies. D'Arcy and Devaraj (2012) also report that employees may be less likely to misuse technology if there are formal sanctions, e.g., risk of discipline or termination. Those authors report that informal sanctions are even more effective than are formal sanctions. Specifically, employees who anticipate social and self-disapproval upon policy violation are less likely to do so. Training, therefore, should focus both on what to do/not do and on the consequences of non-compliance.

Recommendations from US-CERT

The following recommendations from US-CERT are useful for all computers but are especially important for mobile devices ("Security Tip," 2010):

1. Do not allow applications and sites to save passwords. Saving passwords allows anyone accessing a device to access to all of the accounts and systems the device can access.
2. Store especially sensitive data separately from devices that use it, such as on an encrypted flash drive attached to a key ring.
3. Install and maintain anti-malware, antivirus, and firewall software.
4. Backup important information to a secure location. Note that this is important even if the primary storage is cloud-based, since the possibility always exists that information could be accidentally or intentionally damaged, or that the cloud provider could have a storage malfunction. Off-line, non-erasable media like CD-ROM or DVD-ROM are recommended for the best protection, and sensitive information should be encrypted in case the backup falls into the wrong hands.

US-CERT (United States Computer Emergency Readiness Team) is a government-sponsored site devoted to improving cybersecurity ("US-CERT," 2014). The site provides numerous recommendations, many of which are easily readable by managers and users, and some of which are cited herein. More thorough and technical information is available from the Carnegie Mellon University Software Engineering Institute CERT® site ("The CERT Program," 2014), which helped create US-CERT and works closely with it. Organization IT security personnel should visit the sites (http://www.us-cert.gov/ and http://www.cert.org/) periodically and ensure that the recommendations found on them are followed. Apple® mobile device security information is available from "Deploying iPhone and iPad Security" (2012) while the "Android Tips" site (2014) provides some guidance for Android devices.

Getting Back to Work

Finally, if a device is lost, stolen, or confiscated, the user faces another problem besides compromised data: "How will I be able to work?" The same is true if a device merely fails. Cloud computing would seem to be an advantage in this case, since another device could be purchased, therefore making systems quickly available again. However, a new system would probably not come set up for a reasonable level of security, thereby allowing it to easily be compromised. A better solution would be to have more than one device, so an alternate can be used if the primary device is not available. This is probably one reason why so many road warriors carry multiple devices as reported by Ragan (2012).

CONCLUSION

The concepts discussed herein are applicable to organizations that have employees who access company information systems while located physically outside the organization. The systems may be located on a device carried by the employee, but it is increasingly common to use a device that connects to organizational systems by network (particularly the Internet). Such systems may be located within the organization's control but are increasingly cloud-based. So-called "road warriors" rely heavily on using systems in this manner. Road warriors and their electronic devices raise many threats to information system security. A lost or damaged device may result in loss of valuable information that is not stored anywhere else. Systems and their data can be compromised by access to a device or system by an unauthorized person as well as by the monitoring of unsecure communications. Threats may be physical, such as when a device is stolen, confiscated by authorities, or accessed without permission. Electronic risks include hacker attacks and malware infections. Internal systems that are otherwise secure can be penetrated when a compromised device is brought inside the organization and connected to them.

The increasing use of cloud computing brings both advantages and disadvantages. Although cloud storage may prevent device loss or failure from causing data loss, there are risks associated with depending on the Internet to do meaningful work and with having critical systems located outside of the organization's control. The fact that cloud systems can be used from anywhere means that they can be compromised from anywhere. Additional risk comes from the growth of BYOD. Allowing employees to use their own devices means that IT staff will have more device types to worry about. The employees will also expect to use their devices for personal purposes, which will increase exposure to malware and other risks. In addition, company secrets can be compromised by inappropriate use of social media even if the device being used is secure.

Recommendations are provided herein that should minimize the impact of the stated risks. Actual implementation of some of these recommendations will require the skills of professional IT staff. Others (like setting a device passcode) are simple enough for anyone to do. The choice of which precautions to implement should take into account both the degree of risk for the particular user (such as whether a device is used in an especially dangerous location) and the value of the respective system and/or information.

Finally, it should be noted that no set of precautions can completely eliminate the risk to systems used and/or accessed by road warriors. Accidents and mechanical failure can happen, users can be careless, determined criminals can find a way to steal devices, and "zero-day" vulnerabilities apply to every device that connects to systems by network. Care should be taken

to balance the benefit of using systems away from the organization against the risk. As discussed by Fisher et al. (2010), some systems may be too sensitive to risk their use or access from outside the organization's control.

REFERENCES

About 2-step verification (2014). Google.com. Retrieved September 4, 2014 from: https://support.google.com/accounts/answer/180744?hl=en

Android Tips (2014). Stanford University. Retrieved September 5, 2014 from: https://itservices.stanford.edu/service/mobiledevice/management/android_tips

Bector, S. (2009). "Your laptop, please:" the search and seizure of electronic devices at the United States border. *Berkeley Technology Law Journal; 2009 Annual Review*, 24(1), 695-718.

Blyth, A. (2011, September/October). Up in the air. *Buying Business Travel*, (52), 64-66.

Bohon, C. (2011). How to restrict functions in ios. *Mac|Life*. Retrieved October 5, 2011 from: http://www.maclife.com/article/howtos/how_restrict_functions_ios

Brown, M. (2014, May 5). Tested: 6 new travel routers that can deploy a secure Wi-Fi network almost anywhere. *Pcworld.com*. Retrieved August 28, 2014 from http://www.pcworld.com/article/2150741/tested-6-new-travel-routers-that-can-deploy-a-secure-wi-fi-network-almost-anywhere.html

Burt, J. (2011). BYOD trend pressures corporate networks. *eWeek*, 28(14), 30-31.

Cohen, R. (2013, April 16). The cloud hits the mainstream: more than half of U.S. businesses now use cloud computing. *Forbes.com*. Retrieved August 29, 2014 from http://www.forbes.com/sites/reuvencohen/2013/04/16/the-cloud-hits-the-mainstream-more-than-half-of-u-s-businesses-now-use-cloud-computing/

Constantin, L. (2012, September 14). Over half of Android devices have unpatched vulnerabilities, report says. Retrieved September 4, 2014, from http://www.pcworld.com/article/262321/over_half_of_android_devices_have_unpatched_vulnerabilities_report_says.html

Cox, J. (2012, July 16). IT groups eschew BYOD: workers to carry company-owned tablets. *Network World*, 29(13), 1-16.

D'Arcy, J.D. & S. Devaraj (2012). Employee misuse of information technology resources: testing a contemporary deterrence model. *Decision Sciences Journal*, 43(6), 1091-1124.

Deploying iPhone and iPad Security Overview (2012, March). Retrieved September 4, 2014 from: https://ssl.apple.com/ca/ipad/business/docs/iOS_Security_Mar12.pdf

Device Administration (2014). Retrieved September 4, 2014 from: http://developer.android.com/guide/topics/admin/device-admin.html

Drew, J. (2012). Managing cybersecurity risks. *Journal of Accountancy*, 214(2), 44-48.

Eddy, N. (2010). Business travelers relying on social networking tools, survey finds. *Channel Insider*, 1.

Find My iPhone, iPad, and Mac (2014). Apple.com. Retrieved September 4, 2014 from: http://apple.com

Fisher, W., D. Tinsley & R. Strader (2010). Managing unavoidable risks in cloud computing. *Journal of Business Issues*, 2009(1), 5-16. Retrieved August 29, 2014 from http://uwf.edu/media/university-of-west-florida/colleges/cob/deans-office-pdfs/journal-of-business-issues/JBI2009-1.pdf

Geelan, J. (2009). Twenty-one experts define cloud computing. *Cloud Computing Journal*. Retrieved June 8, 2014 from, http://cloudcomputing.sys-con.com/node/612375

ISO 27001 Security (2012). Retrieved September 8, 2012 from: http://www.iso27001security.com/

Julisch, K. & Hall, M. (2010). Security and control in the cloud. *Information Security Journal: A Global Perspective*, 19(6), 299-309. doi: 10.1080/19393555.2010.514654

Lanois, P. (2011). Privacy in the age of the cloud. *Journal of Internet Law*, 15(6), 3-17.

McMillan, G. (2011). Retrieved June 8, 2014 from, http://techland.time.com/2011/03/23/40-of-social-network-users-attacked-by-malware/

Mogull, R. (2011). How to use your ipad securely. *Macworld*. Retrieved September 4, 2014 from: http://www.macworld.com/article/1160313/ipad_security.html

Multi-factor authentication (2014, September 1). *Wikipedia*. Retrieved September 4, 2014 from: http://en.wikipedia.org/wiki/Multi-factor_authentication

Nakashima, E. & W. Wan. (2011, September 27). On red alert over cyber-spying. *The Washington Post*, Met 2 Edition, A-Section, A01.

Neff, J. (2012, April 3) P&G Bans Use of Pandora, Netflix for Employees. *Ad Age|digital*. Retrieved March 3 , 2014 from: http://adage.com/article/digital/p-g-bans-pandora-netflix-employees/233890/

Panton, B.C., J.M. Colombi, M.R. Grimaila, & R.F. Mills (2014, January). Strengthening DoD cyber security with the vulnerability market. *Defense Acquisition Research Journal*, 21 (1), 465-484.

Pash, A. (2009, February). 15 tech secrets for the serious road warrior. *PC World*, 27(2), 106-108.

Piscitello, D. (2012). Security and xDSL connections. WatchGuard Technologies, Inc. Retrieved September 9, 2012 from: http://www.corecom.com/external/livesecurity/part2.html

Puhakainen, P. & M. Siponen (2010, December). Improving employees' compliance through information systems security training: an action research study. *MIS Quarterly*, 34 (4), 767-A4.

Ragan, S. (2012, August 20). Security risks in motion: 55% of road warriors carry three or four devices. Retrieved June 8, 2014 from, http://www.securityweek.com/security-risks-motion-55-road-warriors-carry-three-or-four-devices

Remote Wipe a Mobile Device (2012). Google.com. Retrieved March 4, 2014 from: http://support.google.com/a/bin/answer.py?hl=en&answer=173390

Rhodes, R. (2012, June 18). BYOD is a minefield. *Network World*, 29(12), 24-25.

Riley, M. & Vance, A. (2011, July 25). The code war. *Bloomberg Businessweek*, (4239), 50-57.

Ristov, S., Gusev, M., & Kostoska, M. (2012, March). Cloud computing security in business information systems. *International Journal of Network Security & Its Applications*, 4(2), 75-93. doi:10.5121/ijnsa.2012.4206

SAS 70 Overview (2012). Retrieved September 8, 2012 from: http://sas70.com/sas70_overview.html

Schroeder, S. (2014). BadUSB can turn thumb drives into cyberweapons. *Mashable.com*. Retrieved October 3, 2014 from http://mashable.com/2014/10/03/bad-usb/

Schultz, B. (2011, April 4). Public vs. private clouds why not both? *Network World*, 28(7), 20-21.

Security Tip (ST04-020) Protecting Portable Devices: Data Security (2010, January 27). US-Cert. Retrieved September 2012 from: http://www.us-cert.gov/cas/tips/ST04-020.html

Smith, R. (2010). *Least privilege security for windows 7, vista, and xp*. Olton Birmingham, GBR: Packt Publishing Ltd. Retrieved from: http://site.ebrary.com.steenproxy.sfasu.edu:2048/lib/sfasu/docDetail.action?docID=10441100

The CERT Program (2014). Software Engineering Institute, Carnegie Mellon University. Retrieved September 5, 2014 from: http://www.cert.org/

US-CERT United States Computer Emergency Readiness Team (2014). US-CERT. Retrieved September 5, 2014 from: http://www.us-cert.gov/

Walters, P. (2012). The risks of using portable devices. US-CERT. Retrieved from: http://www.us-cert.gov/reading_room/RisksOfPortableDevices.pdf

Website Temporarily Down (2012). Retrieved November 12, 2012 from, http://community.prezi.com/prezi/topics/website_temporarily_down-lmi4z

Whitwam, R. (2012, February 2). How to properly secure your iphone or android device. *Extremetech*. Retrieved from: http://www.extremetech.com/computing/116635-how-to-properly-secure-your-iphone-or-android-device

ARCHITECTURE ANALYSIS OF BUSINESS INTELLIGENCE PRODUCTS IN JAPAN

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ABSTRACT

This paper aims to identify the key success factors of the Japanese business intelligence (BI) market, by analyzing the "product architectures" of the winners' BI software and consulting services. The market share is used as the definition of win. Results highlight the following features of winners' architectures: the software and consulting services' architectures were "closed" at first, and consulting services' architecture changed from "closed" to "open" first, followed by that of the software. The losers' product architectures had the opposite dynamics: the software's architecture became "open" first, followed by that of the consulting services. These results indicate that differences in the dynamics of product architectures could be the dominant success factors in the BI market.

INTRODUCTION

Today, business intelligence (BI) has attracted the attention of the public given the increase in the power of the PC. BI is a concept, methodology, activity, or IT system that holds a significant amount of data internally and, externally and enables a company's results to be analyzed, with the results utilized during business administration decision making (NTT Data Corporation, 2009). Figure 1 illustrates a common BI system structure. In the past, SCM (supply chain management), CRM (customer relationship management), POS (point of sales), or ERP (enterprise resource planning) systems were installed at a company but the data were managed separately for each system. In a BI system, ETL (extract, transform, load) manages all of the data in all of a company's systems through which the data are interrelated with one another. The data are stored in a DBMS (database management system) for DWH (data warehouse) purposes and used for statistical analyses, data mining, text mining, or simulations. The analytic results are displayed using report tools or dashboard systems and are shared across the entire organization.

To achieve its goals, simply installing a BI system is insufficient; therefore, how a company uses a BI system after its installation is a key success factor and an important feature of such systems. The methods for analyzing data using BI systems cannot be manual because they depend on the purpose of the installation, the business situation, or the condition of the data. Therefore, providing consulting services to develop methods for utilizing a BI system is important to customers' success, and the excellence of consulting services is said to be strongly related to the success or failure of BI vendors.

This paper uses the product architecture framework to attempt to clarify the key success factors (KSFs) of a BI vendor's business that provides the combination of BI software and consulting services. The following are the research questions that this paper addresses.

What are the strategies for software products and consulting services that result in success in the BI market?

How do the product and service strategies affect a company's competitive advantage?

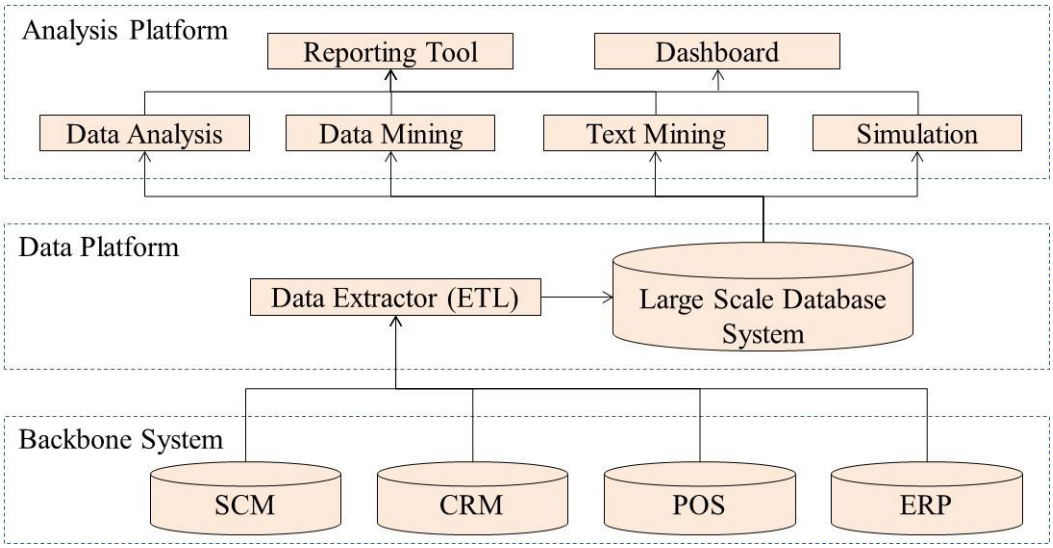


Figure 1. Common structure of a BI system

PREVIOUS STUDIES ON PRODUCT ARCHITECTURE AND THEIR RELATIONSHIP TO THIS STUDY

Product architecture is a concept that expresses the relationship among the components of a product and is used to discuss the alignment between organization structure and product architecture (Baldwin & Clark, 2000; Fujimoto, Takeishi, & Aoshima, 2001). Product architecture consists of two parameters. One parameter is the modularity among a product's components, and the other parameter is the openness of the interface among the components. Product architecture is widely used to analyze automobile, semiconductor, software, and financial service industries (Fujimoto, Takeishi, & Aoshima, 2001).

For example, in the analysis of the automotive industry, the product architecture dynamics of car production systems and partnerships among suppliers were analyzed by comparing Japanese automotive companies with European companies (Takeishi, Fujimoto & Ku, 2001). The result revealed that there were some modularization trends in automotive industries, in which the integral architecture had been common.

In the analysis of the software industry, a development project relating to Linux OS (operating system) for personal computers was analyzed using product architecture (Koyama & Takeda, 2001). In the first Linux project, the software structure was strictly defined; however, the size of the software increased from 320,000 bytes in September 1991 to 90,000,000 bytes in May 2000, which means that the efficiency of the software had declined. This result indicates that it is

highly difficult to define the module structures and the interface between modules at the inception of software development projects.

In the analysis of the service industry, Japanese financing services were analyzed using product architecture (Usuki, 2001). Before the 1980s, Japanese financial services were highly integrated and were known as the Megabank system. After the transformation to an open market, known as the Financial Big Bang in the 1990s, there have been an increasing number of Western-style modular products in the Japanese financial market. In order to adopt such a trend, this paper proposed that Japanese financial companies have to develop a strong relationship with their customers, and to establish capabilities for value-added consulting services.

Currently, complex products that consist of more than two components, such as an "embedded system" in some appliances, have increased their presence in the market. Ito (2005), Park (2005), and Saeki (2009) insisted on the necessity of an analytic framework for such products, which have both integral and modular characteristics at the same layer, making analysis difficult using an existing product architecture framework.

Ito (2005) proposed a "System Architecture" framework to analyze such products (e.g., embedded systems) and proved the validity of the framework by analyzing digital cameras and car navigation systems. "System Architecture" is a 2-by-2 matrix framework where the horizontal axis shows whether the product architecture of software is "open" or "closed" and the vertical axis shows whether the product architecture of hardware is "open" or "closed." The research result shows that the "System Architecture" framework can facilitate the analysis of a product that consists of both software and hardware elements. Ito (2005) proved that the dynamics of product architecture on the "System Architecture" matrix would be different according to the strategies developed by each company, and that "System Architecture" is useful in the real business world.

By analyzing System LSI, Park (2005) indicated that both integral characteristics that differentiate a product and modular characteristics that shorten R&D and production time could exist at same time.

As revealed in this section, prior studies on product architecture analyzed hardware, software, and services, and the combination of hardware and software. However, because prior studies do not consider the combination of software and services, the BI system discussed in this paper cannot be analyzed using existing frameworks. Therefore, this paper proposes a new analysis framework to analyze a product that consists of both software and services.

Cusumano (2004) indicated that a software company requires different capabilities for product development and the provision of solution services, and that the manner in which they are combined is important for success.

ANALYSIS METHOD

Because the BI system has separate markets for each category shown in Figure 1 (e.g., text mining, data mining or data analysis), analyses were performed respectively. This paper compares the product made by the most successful company with the products made by other companies to attempt to extract the typical characteristics of the most successful company.

The analytical method consists of two steps. First, the criteria for why users selected their BI products are extracted from interviews with users of each BI product. The objective of this step

is to clarify the applicability of the use of the product architecture framework because the framework can be used only to analyze the product itself. This analysis assumed that the superiority of the product itself—not price or logistics—including software and services, is the key success factor in a BI business.

Second, the analysis extracts the reasons why the criteria extracted from the first step were established using a new product architecture framework that this paper proposed. "Success" has several definitions, such as profits, customer satisfaction, or the level of goal attainment of cost cutting (Griffin & Page, 1993). This paper uses market share as the definition of success because it is objective and data on market share are easily obtained. This paper extracted market share data from ITR Market View 2010 (ITR Corporation, 2010).

STEP 1: Extraction of product selection criteria of BI system users

The reasons for a user selecting a BI vendor and purchasing its offerings are extracted using semi-structured interviews. First, the interview clarifies the extent to which an interviewee was involved in the BI product selection process. Second, the user is asked whether the pre- assumed criteria are important to the selection. The pre-assumed criteria were referred from the three disciplines (Product Leadership, Customer Intimacy, and Operational Excellence) defined by Treacy and Wiersema (1995). If the results of the interview show that Product Leadership is the most important selection criterion, then the analysis done in the next step, which utilizes the product architecture framework, is reasonable.

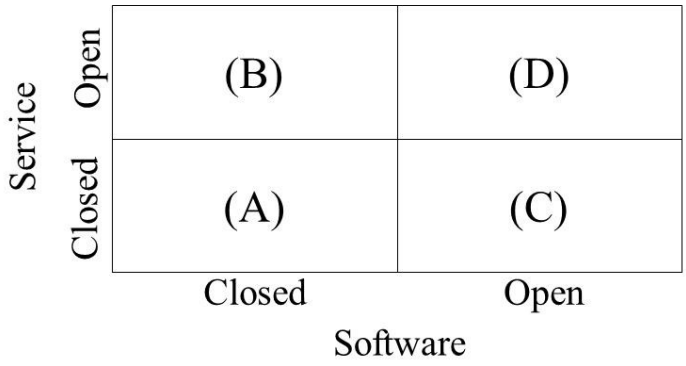
STEP 2: Product architecture analysis of BI products

By expanding the "System Architecture" framework (Ito, 2005), which consists of the product architectures of software and hardware, the analysis framework consisting of the product architectures of software and services will be used for the analysis of the combined software and services products, such as BI. Figure 2 shows the new framework that is proposed. The vertical axis shows the services product architecture and the horizontal axis indicates the software product architecture. The time-variable dynamic changes on the both axes of product architecture are examined to highlight the characteristics of successful products. As described in the section on previous studies, Ito (2005) proved the validities of the 2-by-2 matrix framework shown in Figure 2, which consists of two different components such as software and services.

Figure 2 shows that a vendor that provides a product in area (A) may provide a small variety of software and services because both are provided by only one company. A vendor in area (B) may have a strategy to expand its sales channel or to enforce its consulting capabilities. A vendor in area (C) should consider not being a software vendor but instead being a solutions provider because a solutions provider offers combined software applications for optimal solutions. A vendor in area (D) should be a coordinator of BI software and consulting services provided by other companies.

Suarez & Cusumano (2009) proved the roles of services in platform businesses, including software. The result shows that services can help obtain feedback from customers of the platform, and to increase the value of the platform itself. Cusumano (2004) indicated that a software

company requires different capabilities for product development and the provision of solution services, and that the manner in which they are combined is important for success.



Business model patterns
(A): Closed lineups of software and services (vertical integration).
(B): Consulting services for its BI software are provided by other companies.
(C): Basically vertical integration but expand software functions through horizontal division of labor.
(D): Open software and services are combined with any other software and services in the market.

Figure 2 Proposed product architecture framework

This discussion of product architecture emphasizes the importance of clarifying the layer of product architecture discussed. Therefore, the layers discussed in this paper are illustrated in Figure 3 using a text mining product as an example. In text mining software, the text data input are processed using a morphological analyzer, and the output is used for statistical tests or the development of the appearance frequency ranking of words, and so on. The output is processed with commonly used analysis modules such as multivariable analysis. Moreover, text mining software may be concatenated with other systems such as a company's existing internal IT system.

Consulting services are provided to ensure that a BI system is utilized properly and effectively. A BI product has six layers ((1) to (6)) in its product architecture, which consists of both software and services. This paper uses layer (4), the interface between BI software and other systems, to analyze software. In contrast, layer (5), the interface between BI software and consulting services, is used to analyze services because BI vendors are differentiated using the characteristics of layers (4) and (5). The other layers—(1), (2), (3), and (6)—should always reflect an open and modular architecture; therefore, they need not be analyzed.

When information for the interface at layer (4) is hidden in a company or protected by a NDA (non-disclosure agreement), the software product architecture may be labeled "closed." In this case, the variation in connectable systems is small; however, changing the specification of interface (4) is relatively free and easy because all of the connectable systems may be managed.

In contrast, open software architecture indicates that the general public may access interface (4). In this case, the variation in connectable systems is large; however, changing the specification of interface (4) is difficult because the number of systems is too large to manage.

A closed services architecture indicates that the consulting services are provided only by a BI software vendor. In contrast, an open services architecture indicates that the consulting services are provided by many other companies.

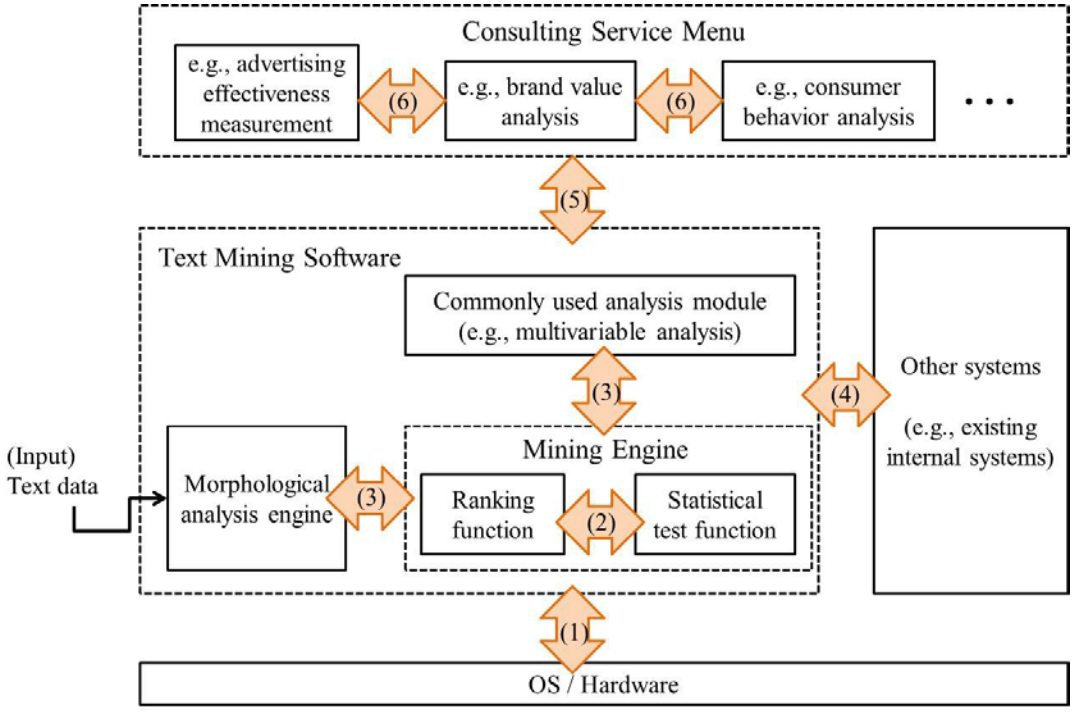


Figure 3 Definition of interface (the case of text mining)

Working hypotheses

From surveys on previous studies, the following hypotheses were constructed. Specifically, Hypothesis 1 (H1) was constructed from the research result of Chesbrough & Kusunoki (2001), which shows the circular dynamics of product architecture from integral to modular to integral. Hypothesis 2 (H2) was developed by combining the research results of Ito (2005) and Porter (1980). Ito (2005) indicated that the differences of each company's strategy can be shown as different dynamics of the "System Architecture" framework, and Porter (1980) indicated that better strategy begets better business performance. Hypotheses 3 to 5 (H3, H4, and H5) were developed by using the research result of Clark & Fujimoto (1991), which proved that the cooperative networks among suppliers, knowledge transfers using the networks, and utilization of the transferred knowledge for product development effectuated the long-lasting competitive advantage of Japanese automotive companies.

H1 *BI vendors' strategies may be illustrated as time-variable dynamic changes in the matrix shown in Figure 2.*

H2 *The dynamic changes of successful vendors are different from those of unsuccessful vendors.*

H3 *Successful vendors show dynamic changes from area (A) to area (B) to area (D). The reasons for the dynamics are as follows.*

A vendor moving from area (A) to area (B) obtains new knowledge about various consulting methods from other companies that provide consulting services and may gain the ability to penetrate new markets. Additionally, such a vendor is able to feed the new knowledge back to its software development division to improve its software.

When a vendor reaches area (D) in Figure 2, it is able to design optimal specifications for interface (4) shown in Figure 3 because it has a large and adequate amount of knowledge about the requirements for interface (4), which was obtained from other consulting companies. Then, the vendor discloses the specifications of the interface and obtains further knowledge for innovation from additional vendors.

H4 *In contrast, unsuccessful vendors move from area (A) to area (C) to area (D). The reasons for these dynamics are as follows.*

When a vendor moves from area (A) to area (C), it must define the specifications of interface (4) using only the knowledge developed internally from its consulting services. Therefore, interface (4) should not be expansible technically, indicating that the vendor provides only a poor variety of solutions.

H5 *A vendor that does not reach area (D) and remains in area (A), area (B), or area (C) cannot be successful for the following reason.*

Compared with a vendor that reaches area (D), a vendor that remains in area (A), area (B), or area (C) has little knowledge about software development and consulting services; therefore, it cannot develop competitive advantages.

CASE STUDIES OF BI VENDORS

This section introduces several incidents of BI vendors that relate to the change in software and services product architecture. Table 1 illustrates the market share of BI vendors in Japan during fiscal year 2009 (ITR Corporation, 2010). The news was extracted from the homepages of BI vendors on the Internet and from newspaper articles, and they are ordered by time. The factual accuracy of several vendors' information was verified through interviews.

Text mining market

In the text mining market, the most successful vendor is Nomura Research Institute. The Trueteller software was first developed for use within the company. Nomura attempted to differentiate by analyzing large amounts of text data, a task that was technically difficult at that time. Because the software was easy to use, in September 2001, Nomura decided to sell it in the market. From the starting point, the software was clearly standalone, indicating that the software and services architectures were "closed" at that time. In December 2002, Nomura then decided to form an alliance with SAP AG, a company with significant experience in CRM systems, and with Transcosmos Inc in April 2004, a company with significant knowledge of market data analysis. At that time, the services architecture may be said to have changed from "closed" to "open."

Table 1 Market shares of BI vendors in Japan

Market	Vendor Name	Market Share (2009 fiscal year)
Text Mining	Nomura Research Institute	43.9%
	IBM (SPSS)	15.8%
	Qualica	6.8%
	Mathematical Systems	3.2%
Data Mining	IBM (SPSS)	45.9%
	Teradata	20.3%
	Mathematical Systems	8.8%
Data Analysis	SAP	24.8%
	Oracle	15.4%
	IBM (Cognos)	12.6%
	WingArc Technologies	8.2%
	Ashisuto	8.0%
	Fujitsu	5.8%

In August 2005, Nomura jointly developed patent portfolio software with NRI Cyber Patent Ltd and the VOC21 (Voice of Customer 21st) system with Matsushita Electric Works (currently Panasonic Corporation), which were connected using Trueteller. The software product architecture may be said to have changed from “closed” to “open.”

In October 2002, IBM (SPSS was acquired by IBM in 2009) launched a text mining software package, Text Mining for Clementine. The software had a modular architecture because it consisted of several open modules (i.e., morphological analysis module developed by a university) but originally had no interfaces for concatenation with other software, giving it a “closed” architecture. Then, in October 2002, CEMI (Clementine External Module Interface) was developed that could interface with other software; thus, the product architecture changed from “closed” to “opened.” Subsequently, in February 2003, IBM launched a partnership program with NCR Japan Ltd, NTT Learning Systems Corporation, Fujitsu Broad Solution & Consulting Inc., and Hewlett Packard Japan, Ltd. for consulting services and maintenance. The main purpose of the program was to expand sales channels; however, the partners clearly had adequate data analyses and consulting services capabilities. Therefore, the services product architecture is said to have shifted from “closed” to “open” at that time.

In January 1998, Qualica Inc. launched text mining software called VextMiner. The software initially worked alone but was connected with a Chinese morphological analysis module developed by Basis Technology Corporation in December 2003, and with the speech recognition engine AmiVoice, provided by Advanced Media Inc., in November 2004. Therefore, the software’s product architecture is said to have changed from “closed” to “open.” In contrast,

because only Qualica provided consulting services for VextMiner, the services product architecture has been constantly "closed."

In April 2005, Mathematical Systems Inc. launched Text Mining Studio (TMS). Initially, TMS was a standalone software package, making the software and services product architectures "closed." In September 2008, the NICT (National Institute of Information and Communication Technology) then developed TMS into a new system that extracts and visualizes proper nouns and related numerical numbers. The external interface of TMS was strictly defined and disclosed to the public at this time; thus, the software product architecture is said to have changed from "closed" to "open." In contrast, consulting services are provided only by Mathematical Systems (meanwhile, "user conferences" are convened at which several professors and researchers introduce new analysis methods and research results extracted using TMS, but is not a consulting service); thus, the services architecture is said to have been constantly "closed."

Data mining market

In the data mining market, IBM (SPSS was acquired by IBM in 2009), which has the top market share (a successful vendor), launched the text mining software, Clementine, in May 1999. Initially, Clementine was used not for businesses but for the analysis of psychological questionnaires. IBM decided to collaborate with a subsidiary company of NTT Corporation in November 2000 and with Compaq Computer Corporation in November 2001. IBM then launched a sales partnership program with 10 business partners, including ITOCHU Techno- Solutions Corporation, NTT Learning Systems Corporation, and Fujitsu Broad Solution & Consulting Inc. The services product architecture is said to have initially shifted from "closed" to "open." In contrast, as is the case with text mining software, the CEMI external interface was defined by October 2002.

In July 2003, a system to support marketing activities using the Internet was then developed by connecting Clementine with a system provided by Hitachi Systems Ltd. Cleo, a tool for developing Web applications on the Clementine system, was launched in April 2004. These releases indicate that the software product architecture changed from "closed" to "open."

Because Teradata Corporation provided little information related to product architecture until now, an in-depth interview was conducted with an employee in the Business Solution Department. The first product was the second version of Teradata Warehouse Miner (TWHM), which was launched in 1998. The first version of TWHM was developed to generate SQL (Structured Query Language) data only for consultants within Teradata and was not for sale. The second version did not have an external interface for connecting to other software, and consulting services were provided only by Teradata. In 2003, Teradata developed the Model Manager software that worked with TWHM and defined specifications for an external software interface. Subsequently, the external interface connected with the system provided by SAS Institute Inc., indicating a change in the software product architecture from "closed" to "open." In contrast, consulting services were provided only by Teradata, indicating a constantly "closed" services architecture.

In July 2004, Mathematical Systems Inc. launched the fourth version of Visual Mining Studio (VMS). Previously, information could not be obtained from open news data; however, the

fourth version of VMS proved to be the first software package with an external interface. The fourth version had the ability to obtain data automatically from Microsoft Excel and was callable from external software or script programs, thus changing the product architecture from "closed" to "open." In contrast, consulting services were provided only by Mathematical Systems, indicating a consistently "closed" services architecture.

Data analysis market

In the data analysis market, the number one product is SAP Business Objects (SBO) provided by SAP AG (a successful vendor), a package installed by Kanbara Yakugyo (currently ASTIS Co. Ltd.) in 1996. At that time, SBO worked in standalone mode for the analysis of stored sales data. SAP announced an alliance with JFE Systems Inc. in June 2003 and with NEC Soft Ltd in September 2003 for BI analysis consulting services. These alliances indicate a change in the services product architecture from its initial "closed" to "open." SAP announced an alliance with BearingPoint Inc. (taken over by PricewaterhouseCoopers Co Ltd) in June 2008 and with SCSK Corporation in August 2008 for BI analysis consulting. At approximately the same time, SBO was given an external interface with SAP ERP, indicating a change in the software product architecture "open."

In October 2004, Oracle Corporation launched new data analysis software called Oracle Daily Business Intelligence (ODBI). At that time, information on an external interface to other software and alliances for consulting services with other companies did not exist, indicating "closed" software and services architectures. In November 2004, Oracle announced an alliance for BI analysis consulting services with Siebel CRM Systems Inc., indicating a change in the services architecture to "open." In October 2005, ODBI then started working with the consolidated accounting software STRAVIS, indicating a change in the software architecture to "open."

Data analysis software by Cognos was on the market by January 2008. Cognos Corporation was acquired by IBM in January 2008, and the Cognos software and consulting services businesses continued as a division of IBM. Cognos announced an alliance for BI analysis consulting services with Fujitsu Limited in February 2003 and with IBM in April 2003, indicating a change in the services product architecture from "closed" to "open." In September 2003 and November 2003, the Cognos software package started working with two software applications for reporting analysis results on Web sites, indicating a change in the software architecture from "closed" to "open."

In April 2004, WingArc Technologies Inc. launched data analysis software called Dr. Sum EA. At that time, information on external software interfaces and consulting services alliances with other companies did not exist, indicating "closed" software and services architectures. Dr. Sum EA then started working with multidimensional high-speed counting software in May 2004 and with the Visualizer software in November 2004, indicating a change in the software architecture to "open." In July 2007, WingArc announced an alliance for solution services with Nexaweb Technologies Inc., indicating a change in the services architecture from "closed" to "open."

Information dated before January 2000 on the data analysis software WebFOCUS as provided by K.K. Ashisuto could not be obtained from open news data. WebFOCUS worked in standalone mode, and no evidence exists of consulting services alliances with other companies in

January 2000, indicating "closed" software and services architectures at that time. In February 205, Ashisuto started a BI system development project with Nihon Unisys Ltd and Microsoft that utilized WebFOCUS as a module, indicating a shift in the software architecture from "closed" to "open." Ashisuto then announced alliances for BI analysis consulting services, sales, and technical support with NUS Ltd and others, indicating a change in the services architecture from "closed" to "open."

In July 2003, Fujitsu Limited launched the data analysis software Interstage Navigator version 6. Information before this time was not found in open news data, and no information on external software interfaces and consulting services alliances with other companies existed at that time. Therefore, the software architecture was "closed." Interstage then began to work with a system provided by Fujitsu Kyushu System Services Limited that put Interstage on the Intranet for information sharing with board members and managers, thus indicating a change in the software architecture to "open." In contrast, BI analysis consulting services were provided only by Fujitsu until now, indicating a consistently "closed" services architecture.

ANALYSIS RESULTS AND DISCUSSION

Analysis results of user companies

For three BI markets—text mining, data mining, and data analysis—telephone interviews were conducted with BI users to clarify the selection criteria for BI vendors. Interviews were extracted from the Web sites of each BI vendor in which typical customers are introduced as case studies. The number of interviews was nine (3), 10 (2), and 15 (5) for text mining, data mining, and data analysis markets, respectively (the numbers in parentheses indicate the number of customers of successful vendors). Before the interviews, the questionnaires were sent to the interviewees.

Table 2 shows the results of the interviews. Figures in the table show the number of interviewees that answered, "This criterion was important for BI vendor selection" and the number of interviewees. The differences between the successful vendors and others are as follows.

Customers of the top share vendors in the market considered consulting services by BI vendors to be important.

Customers of the top share vendors in the market did not consider price to be that important.

In contrast, all customers considered the usability of BI software as very important. Based on these results, analyses of product architecture are quite meaningful for clarifying the key success factors for BI businesses.

Table 2 Analysis results of users' production criteria

Criteria		Users of the most successful vendor	Users of other vendors
Product Leadership	Software	10/10	23/24
	Service	7/10	14/24
Operational Excellence		4/10	15/24
Customer Intimacy		3/10	8/24

*Figures in this table show "Number of users who answered the criterion is important"/ "Number of all users"
*Multiple answers allowed

Analysis results of BI vendors

The dynamics of the product architectures for each vendor were extracted from the case studies in the section on "Case studies on BI vendors" and are shown in Figure 4. The solid lines show the results of top share vendors in each market, and the dotted lines show the results of other vendors. Despite the small number of samples, the results indicate that successful vendors transited from area (A) to area (B) to area (D) in the proposed product architecture framework. In contrast, unsuccessful vendors shift from area (A) to area (C) or from area (A) to area (C) to area (D). Therefore, working hypotheses (1) to (5) as described in the section on "Working hypotheses," may be supported by the results of the dynamics of the product architecture.

Although Oracle and IBM are not successful vendors in the data analysis market, their product architectures shifted from area (A) to area (B) to area (C). The reasons for this shift could be related to the period between the point at which the services product architecture changed from "closed" to "open" and the point at which the software product architecture changed from "closed" to "open." As described in the section on "Working hypotheses," although the length of the periods of successful vendors—Nomura Research Institute in the text mining market, IBM in the data mining market, and SAP in the data analysis market—were 32, 23, and 60 months, respectively, that of unsuccessful vendors—Oracle and IBM—in the data analysis market were 11 and 7 months, respectively. Compared with successful vendors, unsuccessful vendors did not have adequate time to learn about users' needs from other consulting companies in an "open" environment. Thus, unsuccessful vendors could not store enough knowledge to provide superior solutions before the software architecture changed to "open," the point at which the basic software designs were fixed.

Additionally, it was a proven point that the first-mover advantage did not work because the successful vendors in text mining and data mining markets launched the software after other vendors did as described in section on "Case studies on BI vendors" (Nomura launched in 2001 after Qualica did in 1998. IBM in data mining market did in 1999 after Teradata did in 1998).

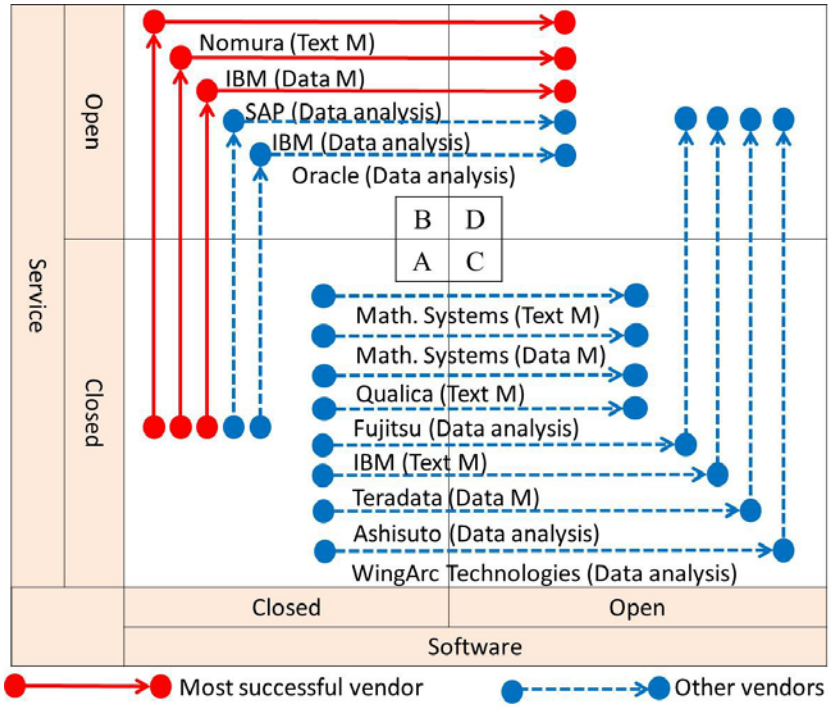


Figure 4 Analysis results of BI vendors' product architectures

CONCLUSION

This paper attempted to extract the key success factors (KSF) of BI businesses using a product architecture framework. The results suggest that a BI vendor provides excellent solutions and obtains high market share by developing relationships with other consulting companies and obtaining knowledge of user needs before modifying the basic design of BI software.

The limitations of this paper are noted as follows. First, only product leadership was discussed in this paper; however, two other disciplines—customer intimacy and operational excellence—that could not be analyzed using a product architecture framework should be analyzed because they represented some of the factors shown in Table 2. The effects of these factors should be examined. Second, this paper discussed only the dynamics of product architecture and estimated what happens during product development; however, the detailed product development process should also be analyzed. In the future, we would like to examine the product development process and reinforce the conclusion of this paper.

REFERENCES

Baldwin, C. Y. and K. B. Clark (2000). *Design rules: Volume 1. The power of modularity*. Cambridge, MA: MIT Press.

Chesbrough H. W. and K. Kusunoki (2001). The modularity Trap: Innovation, technology phase shifts and the resulting limits of virtual organization, in Nonaka I. & D. J. Teece, *Managing Industrial Knowledge*, London, Sage Press.

Clark K. B. and T. Fujimoto (1991). *Product development performance: Strategy, organization, and management in the world auto industry*, Boston, Harvard Business School Press.

Cusumano, M. A. (2004). *The business of software*. Free Press.

Fujimoto T., A. Takeishi and Y. Aoshima (2001). *Business architecture: Strategic design of products, organizations, and processes*. Tokyo, Yuhikaku Publishing Co. Ltd. (in Japanese).

Griffin, A. and A. L. Page (1993). An interim report on measuring product development success and failure. *Journal of Product Innovation Management, 10*(4), 291–308.

Ito, M. (2005). System architecture and innovation. *IEEE International Engineering Management Conference*, 2, 616–620.

ITR Corporation (2010). *iTR market view: DBMS/BI market*. ITR Corporation (in Japanese).

Koyama H. and Y. Takeda (2001). Development technique and structure of software, in Fujimoto T., A. Takeishi and Y. Aoshima (2001). *Business architecture: Strategic design of products, organizations, and processes*. Tokyo, Yuhikaku Publishing Co. Ltd. (in Japanese).

NTT Data Corporation (2009). *BI revolution*. NTT Publishing Co. Ltd. (in Japanese).

Park T. (2005). Strategic management of product architecture. *Business Economy (Osaka University of Economics), 41*, 1–17 (in Japanese).

Porter M. E. (1980). *Competitive strategy: Techniques for analyzing industries and competitors*, Free Press.

Saeki Y. (2009) Architecture-based analysis of product and organization in the product development with multiple-elemental technologies. *Journal of Business Management, 23*, 25–36 (in Japanese).

Suarez F. F. and M. A. Cusumano (2009). The role of services in platform market, *Journal of Organizational Science,* 42(4), pp.4-20 (in Japanese).

Takeishi A., T. Fujimoto and S. Ku (2001). Modularization in automotive industry, in Fujimoto T., A. Takeishi and Y. Aoshima (2001). *Business architecture: Strategic design of products, organizations, and processes*. Tokyo, Yuhikaku Publishing Co. Ltd. (in Japanese).

Treacy, M. and F. Wiersema (1995). *The discipline of market leaders: Choose your customers, narrow your focus, dominate your market*. Perseus Books.

Usuki M. (2001). Architecture and competitiveness of finance industry, in Fujimoto T., A. Takeishi and Y. Aoshima (2001). *Business architecture: Strategic design of products, organizations, and processes*. Tokyo, Yuhikaku Publishing Co. Ltd. (in Japanese).

A CONCEPTUAL MODEL FOR MOBILE BANKING ADOPTION

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ABSTRACT

Despite the steady growth of Internet banking and mobile banking, only half of adults in the U.S. use online banking, with the other half still visiting physical branches for their banking services (Fox, 2013). For years, studies are being conducted in the IS field using the Technology Acceptance Model (TAM) in order to determine the key factors explaining the adoption of online banking. But, due to the privacy concerns and the psychological barriers often associated with conducting transactions in a virtual world, the TAM has proven to be a limited tool. In this study, we revisited the IS literature on mobile banking adoption along with relevant theories from the areas of marketing and psychology in order to develop a conceptual model that would have a potentially greater explanation power. The proposed model emphasizes the role of subjective norms, technological readiness, trust, and perceived critical mass of users. The model is discussed along with the research propositions it implies. The theoretical and practical implications of the study are also discussed.

Keywords: mobile banking, technology adoption, technology readiness, perceived critical mass

INTRODUCTION

Mobile banking refers to the provision of banking services with the help of mobile telecommunication devices. The scope of offered services may include monitoring account balance, transferring funds between accounts, bill payments, and remote check deposit among other services. For years, driven by the need to improve the cost-effectiveness of operations, financial institutions have been using Web technology to provide mobile and Internet banking services and, substantially, reduce the need for personal interactions in the provision of their services (Elliott, Meng, & Hall, 2008). Today most financial institutions in the western hemisphere are offering Internet banking and mobile banking options to their customers. Despite the steady growth of Internet banking and mobile banking, only half of adults in the U.S. use online banking, with the other half still visiting physical branches for their banking services (Fox, 2013). In the IS field, many studies have been conducted using the technology acceptance model (TAM) to determine the key factors explaining the adoption of online banking (Amin, 2007; McKechnie, Yu, 2012). The TAM by Davis (1989) and the TAM2 by Venkatesh and Davis (2000) arguably do not include factors that are meant to capture key elements such as trust and risk associated with the adoption of e-commerce. Given the privacy concerns and the psychological barriers often associated with conducting transactions in a virtual world, the TAM has proven to be a limited tool (Shen, Huang, Chu, & Hsu, 2010). That is why recent studies are

using extended versions of the TAM that include factors such as trust and security concerns. (Chiou & Shen, 2012; Kesharwani & Bisht, 2012; Wang, Hsu, Pelton, & Xi, 2014; Shen, Huang, Chu, & Hsu, 2010; Wang, Hsu, Pelton, & Xi, 2014).

The objective of the present study is to review the IS literature on the adoption of mobile banking along with relevant theories from the areas of marketing and psychology in order to develop a conceptual model that would have a potentially greater explanation power. In the next sections, we will review the relevant literature in order to lay out the theoretical justifications for the concepts to be included in the model. Then, based on the theoretical background, we will discuss the conceptual model along with the research propositions implied. Finally, the paper will discuss the theoretical and potential practical implications of the model.

THEORETICAL BACKGROUND

In the IS field, the technology acceptance model has become a cornerstone for explaining technology adoption and use.

The technology acceptance model

Grounded on the theory of reasoned action or TRA (Fishbein & Ajzen, 1975), the TAM is an implementation of the belief-attitude-intention-behavior relationship. According to the TAM, the actual use of a technology is determined by beliefs a user holds about its *perceived usefulness* and its *perceived ease of use*. Perceived usefulness refers to the extent to which people believe that a technology will help them perform their job better, while *perceived ease of use* refers to the degree to which a person believes that using a particular IT would be free of effort (Davis, 1989). According to the model, potential users' perceptions determine their attitude (favorableness or unfavorableness) toward using a specific technology. The attitude will, then, determine their behavioral intention, that is, their intention to use the technology. Finally, the intention may lead to their actual use of the technology.

Over the years, studies have been conducted using extended versions of the TAM in an attempt to explain the adoption of online banking (i.e. mobile and Internet banking). The study of Vatanasombut, Igbaria, Stylianou, and Rodgers (2008) has found that perceived security has a significant impact on trust in online banking which, in turn, has a significant impact on the continuance intention to use online banking. Shen et al. (2010) also found that technology anxiety, convenience benefit, security cost, and trust in the financial institution have a significant impact on the intention to adopt mobile banking. The study of Singer, Baradwaj, Flaherty, and Rugemer (2012) found that, through its impact on perceived ease of use and perceived usefulness, experience has a negative effect on online banking use. They concluded that as an individual gains experience with more complex and sophisticated features of a bank web site, the intensity and frequency of use diminish. Considering different aspects of risk, the studies of Wang et al. (2014) and Chiou and Shen (2012) confirmed the common sense idea that perceived risk (including financial risk, performance risk, time risk, and psychological risk) has a negative impact on engaging in online banking.

The review of those recent studies reveals a distinctive characteristic of online banking. That is, there is a high risk and a potential for monetary loss for the customer who engage in online banking. Therefore, *trust* must be a key factor at the center of any model that aims at explaining mobile banking adoption.

Trust

From the social psychology perspective, trust is characterized in terms of the expectation and willingness of the trusting party engaging in a transaction (Roca, García, & de la Vega, 2009). It is the main catalyst of most business transactions. According to Mayer, Davis, and Schoorman (1995), trust is a multidimensional concept, typically, defined as the perceived *credibility*, *benevolence*, and *integrity* of a business partner. *Credibility* is the extent to which one business partner believes that the other partner has the required expertise to perform the job effectively and reliably (Wang, Wang, Lin, & Tang, 2003). It is impersonal and relies on reputation. Mayer et al. (1995) defines *benevolence* as the extent to which a trustee is believed to intend to do good to the truster, beyond his or her own profit motives. It can be seen as the extent to which the seller or service provider is genuinely interested in the customer's welfare and has intentions and motives beneficial to the customer (Doney & Cannon , 1997). *Integrity*, on the other hand, refers to the truster's perception that the trustee will adhere to a set of principles or rules of exchange acceptable to the truster during and after the exchange (Mayer et al., 1995). Uncertainty is one of the main reasons explaining online customers' lack of trust (Roca et al., 2009). Typically, in the virtual world, there are two types of uncertainty to deal with: system-dependent uncertainty and transaction-specific uncertainty (Grabner-Kraeuter, 2002). The system-dependent uncertainty is related to all potential technological sources of errors and security gaps like faulty software or hardware devices or security vulnerabilities. System-dependent uncertainty can emerge in the data channel (i.e. the network) or on the "final points" (i.e. customers' desktop system or the seller's or provider's server). Therefore, smooth and secure online transactions depend on the reliability of the hardware and the software as well as the reliability of the technology used to secure the transactions. Transaction-specific uncertainty, on the other hand, is typically, caused by the asymmetric distribution of information between the transaction partners (Grabner-Kraeuter, 2002). In general, the customer does not have as much information as the seller or provider about (a) the quality of the product or the service or (b) the seller's or provider's ability and willingness to perform. This asymmetry is deeper in online transactions because, in part, key elements of personal interactions like facial expression, gestures, and body language are missing in the computer-mediated environment (Grabner-Kraeuter, 2002).

In a virtual world, users' technology readiness can help establish trust.

Technology readiness

Technology readiness encompasses self-efficacy which refers to belief about one's ability to successfully carry out the task at hand (Shen et al., 2010). Parasuraman (2000) defined technology readiness as "people's propensity to embrace and use new technologies for accomplishing goals in home life and at work" (p. 308). It results from mental enablers and inhibitors that determine a person's predisposition to use a new technology. Parasuraman's 2000 study identified two enablers (optimism and innovativeness) and two inhibitors (discomfort and

insecurity) that participate in determining a person's technology readiness. Optimism is the degree to which people believe that technology can benefit their lives and give them more control over their live. Innovativeness is a natural desire to experiment with new technologies. Discomfort is the feeling of lacking both control over technology and the confidence in making technology work. Insecurity was defined as the need for assurance that a technology-based product, service or process will operate reliably and accurately. Because the four dimensions are relatively independent of each other, an individual may harbor both enabler and inhibitor feelings towards technology. It can easily be argued that technology readiness can play a key role in people's intention to use mobile banking. The enabler's aspect of technology readiness can also have a positive impact on people's propensity to trust whereas the inhibitor's aspect would have the opposite impact. Parasuraman (2000) developed a composite technology readiness index that is meant to capture an individual overall readiness to adopt new technologies.

One may be technology-ready, but in order for a bank customer to actually engage in mobile banking, he or she must need it and find it useful. One of the common ways people come to know about innovations and find them useful is through social influence.

Social Influence

In the IS literature, two theoretically distinct types of social influence, *subjective norms* and *critical mass*, have been frequently employed, but typically confounded (Cho, 2011; Venkatesh et al., 2003). The two concepts share several common elements and underlying assumptions. First, both postulate that social influence shapes people's perceptions and behavior. Second, both assume that people face some uncertainty regarding the appropriateness of various actions (e.g. choosing between different technologies to perform a task). That means, usually, before using a technology or a service, people's beliefs about or knowledge of the technology or the service are vague and ill-informed. Therefore, they choose a course of action by relying more on the opinions or the actions of others (Barki & Hartwick, 1994). Third, as the number of users of a technology or a service in their social circle increases, people tend to receive increasing social information or pressure which subsequently increases the chance that they will adopt the same technology or service (Rogers, 1995). But subjective norms and critical mass differs in fundamental ways too.

Critical mass

The TAM suggests that the adoption of a technology or technology-based service depends, fundamentally, on its perceived usefulness and perceived ease of use by the potential adopters (Rogers, 1995). But, from the business perspective, no matter how useful and easy to use a technology or service is perceived to be, it will only be economically viable if there is a critical mass of people adopting it. According to Rogers (1995), critical mass refers to "the point at which enough individuals have adopted an innovation so that the innovation's further rate of adoption becomes self-sustaining" (p. 313). Lou, Luo and Strong (2000) have found that critical mass has a significant impact on groupware acceptance. Ayers, Menachemi, Ramamonjiarivelo, Matthews, and Brooks (2009) have also found that there is a significant increased utility for users of electronic medical records systems when adoption increases among other users. Other studies have found that perceived technology popularity has an impact on the adoption of instant messaging (Strader, Ramaswami, & Houle, 2007), videophone systems (Kraut, et al., 1998), and

the Internet (Zhu & He, 2002). These studies seem to confirm the common sense idea that the higher the number of users of a particular technology in a specific community (workplace, circle of friends, etc.), the more pressure there may be on other people to adopt the technology in question. But how do potential users assess the critical mass? The actual critical mass threshold is difficult to determine, but a particular technology user may have a perception of whether it has been reached or how soon it will be reached (Cho, 2011). As in previous studies like Sledgianowski and (Sledgianowski & Kulviwat, 2009) and Cho (2011), in this study we will use the concept of perceived critical mass (PCM) to refer to users' perception of whether the critical mass threshold is (or how soon it will be) reached.

Subjective norm

Subjective norm refers to the perceived social pressure to engage or not to engage in a behavior (Ajzen, 1991). It is an individual's perception that most of his or her referent others think that he or she should or should not perform a specific behavior like using a specific technology to perform a task. The reason why subjective norm is so prevalent is the belief that following others often leads to better and more accurate decisions, especially when we face uncertainty Griskevicius et al. (2006). Mustonen-Ollila and Lyytinen (2003) reported 16 studies on IT adoption that include subjective norm as a factor. Over the years, consistent with the theory of reasoned actions (Fishbein & Ajzen, 1975), numerous studies have found that subjective norms have a significant impact on people's perception and beliefs about technology (e.g. Homburg et al., 2010; Karahanna and Straub,1999; Schmitz, 1991; Teo, 2010). (Homburg, Wieseke, & Kuehnl, 2010; Karahanna & Straub, 1999; Schmitz & Fulk, 1991; Teo, 2010)

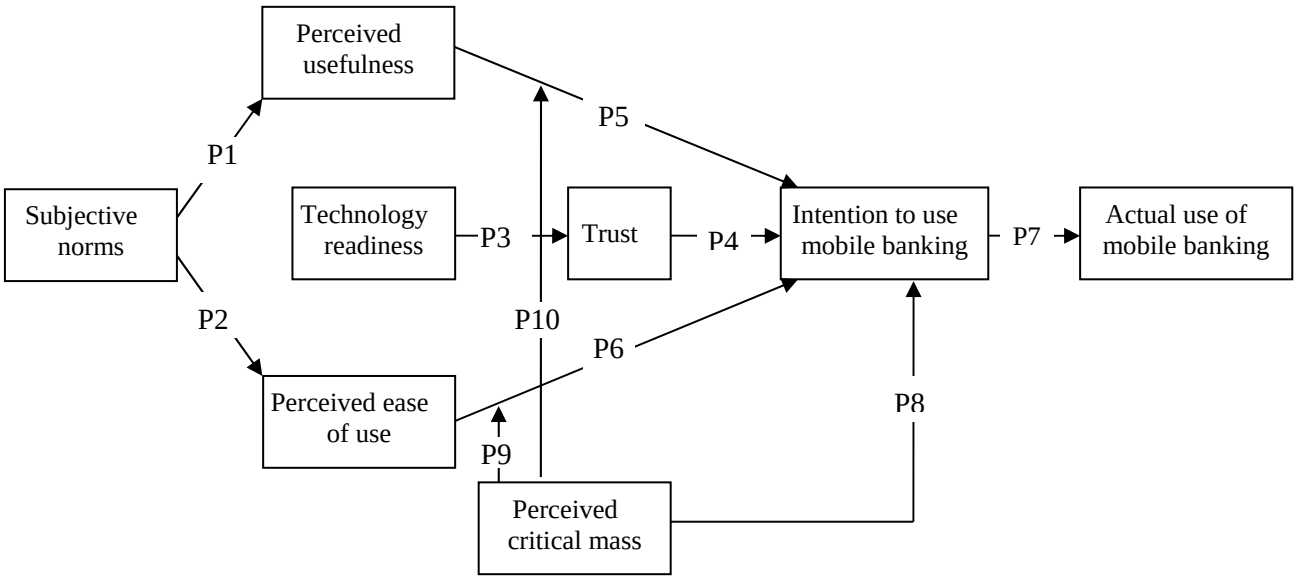
Taking into account the literature reviewed in this section, we propose a research framework along with a series of research propositions.

RESEARCH MODEL AND PROPOSITIONS

Research model

Drawing on the TRA (Fishbein & Ajzen, 1975), we propose that *perceived usefulness* and *perceived ease of use* will have a direct impact on people's *intention to use mobile banking* which, in turn, will impact the *actual use* of mobile banking. As the theory of planned behavior (Ajzen, 1991) suggested, our research model, shown in Figure 1, predicts that *subjective norms* will be an antecedent of *perceived usefulness* and *perceived ease of use*. The model also predicts that people's *technology readiness* will have a direct impact on their *trust* in mobile banking. As in previous studies (e.g. Vatanasombut et al., 2008, Shen et al., 2010), *trust* is presumed to have a direct impact on the *intention to use mobile banking*. Finally, the proposed model suggests that *perceived critical mass* will have a direct impact on the *intention to use mobile banking*, as well as a moderating effect on the relationship between *perceived usefulness* and *perceived ease of use* on the one hand, and the *intention to use mobile banking* on the other hand.

Figure 1: Research model



Research propositions

According to the theory of planned behavior (Ajzen, 1991), subjective norm or perceived social pressure from referent others can impact people's behavior indirectly by shaping their perception over time. That means subjective norm may have an impact on how useful people perceive mobile banking to be. We therefore propose the following:

Proposition 1: ***Subjective norm*** *will have a significant impact on the* ***perceived usefulness*** *of mobile banking.*

If people's perception about the usefulness of mobile banking can be influenced by subjective norm, their perceived ease of use of mobile banking may also be influenced by subjective norm.

Proposition 2: ***Subjective norm*** *will have a significant impact on the* ***perceived ease of use*** *of mobile banking.*

A recent Pew Research survey found that 54% of young adults (18 to 29 years old) owning cell phones use mobile banking (Fox, 2013). The percentage drops to 40% for adults between the age of 30 and 49 despite the same level of cell phone ownership among the two groups (Fox, 2013). One possible explanation could be that younger people are more technology savvy. From that perspective, technology readiness may be a factor that helps younger people overcome the psychological barriers, take risk, and trust virtual entities. We, therefore, propose the following:

Proposition 3: ***Technology readiness*** *will have a significant impact on people's* ***trust*** *in mobile banking.*

Technology readiness has four dimensions, with two of the dimensions (optimism and innovativeness) considered enablers for technology adoption. We propose the following:

*Proposition 3a: **Optimism** will have a positive impact on people's **trust** in mobile banking.*

*Proposition 3b: **Innovativeness** will have a positive impact on people's **trust** in mobile banking.*

The two other dimensions (discomfort and insecurity) of technology readiness are considered as inhibitors for technology adoption. We, therefore propose the following:

*Proposition 3c: **Discomfort** will have a negative impact on people's **trust** in mobile banking.*

*Proposition 3d: **Insecurity** will have a negative impact on people's **trust** in mobile banking.*

Trust was proven to be an antecedent of engaging in online banking (Shen et al., 2010, Vatanasombut et al., 2008). It has multiple dimensions (Grabner-Kraeuter, 2002). In this study, we argue that transaction-specific trust (i.e. trust in the financial institution) and systems-specific trust (i.e. trust in the technology involved in providing mobile banking services) will have a significant impact on their intention to use mobile banking. We, therefore, propose the following:

*Proposition 4a: **Transaction-specific trust** in mobile banking will have a significant impact on the **intention to use** mobile banking.*

*Proposition 4b: **System-specific trust** in mobile banking will have a significant impact on the **intention to use** mobile banking.*

A strong body of research has confirmed the main idea of the TAM, which is *perceived usefulness* and *perceived ease of use* are antecedents of the intention to use IT in general (Mustonen-Ollila & Lyytinen, 2003). For mobile banking, we expect the relationship between *perceived usefulness* and *perceived ease of use* on the one hand and the *intention to use mobile banking* services to be strong. We, therefore, propose the following:

*Proposition 5: **Perceived usefulness** will have a significant effect on people's **intention to use** mobile banking.*

*Proposition 6: **Perceived ease of use** will have a significant effect on people's **intention to use** mobile banking.*

According to the theory of reasoned action, intention which is the cognitive representation of a person's readiness to perform a given behavior is the best predictor of behavior (Fishbein & Ajzen, 1975). We argue that people's intention to use mobile banking will have an impact on the both the frequency and the intensity of their mobile banking services' use. We, therefore, propose the following:

*Proposition 7: The **intention to use** mobile banking will have a positive impact on the **actual use** of mobile banking in terms of frequency and intensity of use.*

According to the diffusion of innovation (DOI) theory, the adoption and spread of an innovation depend on the critical mass of users defined as the point at which enough individuals have adopted the innovation so that its further rate of adoption becomes self-sustaining (Rogers, 1995). Technology users may have their own perception of whether the critical mass of users has been (or is about to be) reached (Cho, 2011). If a customer of a brick and mortar bank customer

has the perception that the critical mass of mobile banking users is (or is about to be) reached, it may make him or her believe that most people are adopting mobile banking, which may have a direct impact on their intention to use the service. We, therefore, propose the following:

*Proposition 8: The **perceived critical mass** of users will have a positive direct impact on the **intention to use** mobile banking.*

Strader et al. (2007) have postulated that critical mass and usefulness, as two value-oriented factors, should be linked when exploring their impact on communication media use. This suggests that perceived critical mass may also have an indirect impact on mobile banking adoption through a possible interaction effect with perceived usefulness. It means that people who have perceived mobile banking as being useful may see their intention to use mobile banking grow stronger as a result of their perception that the critical mass has been (or will soon be) reached. We, therefore, propose the following:

*Proposition 9: The **perceived critical mass** will moderate the impact of **perceived usefulness** on the **intention to use** mobile banking, such that the higher the perceived critical mass, the stronger the impact.*

Likewise, it can also be argued that people who have perceived mobile banking as being easy to use may also see their intention to adopt mobile banking grow stronger as a result of their perception that the critical mass has been (or will soon be) reached. We, therefore, propose the following:

*Proposition 10: The **perceived critical mass** will moderate the impact of **perceived ease of use** on the **intention to use** mobile banking, such that the higher the perceived critical mass, the stronger the impact.*

IMPLICATIONS AND LIMITATIONS

One of the theoretical contributions of this research is a new conceptual model for mobile banking adoption with a potentially greater explanation power compared to the existing frameworks found in the IS literature. The proposed model contributes to the IS literature in two ways. First, it added both positive and negative impacts of technology readiness on the level of trust in mobile banking. Second, it includes a moderating effect of *perceived critical mass*. To our knowledge, this would be the first study in the IS field to include the moderating effect of *perceived critical mass* on the relationship between *perceived usefulness* and *perceived ease of use* on the one hand, and the intention to use mobile banking on the other hand. In terms of practical implications, the testing of the moderating effect of *perceived critical mass* may have some implications for marketing strategy. For example, if it turns out that *perceived critical mass* has a significant moderating effect on the relationship between the *perceived usefulness* and the *perceived ease of use* of mobile banking on the one hand, and the *intention to use to use mobile banking* on the other hand, that means *perceived critical mass* represents a key piece of information that financial institutions offering mobile banking may use in advertising and marketing in general in an attempt to increase mobile banking use. To that end, if regular bank customers are informed through advertising that more and more people are adopting mobile banking, it may have the potential of altering their perception that the critical mass of mobile banking users is (or is about to be) reached, which may have a positive impact on their intention to use the service.

This study has limitations. First, the study is conceptual in nature which means that, although there is a good theoretical foundation for the research propositions, empirical testing is needed. Second, this study didn't include the mediating effect of *attitude* as the TRA (Fishbein & Ajzen, 1975) and the initial TAM (Davis 1989) suggested. This was done for two reasons. One is because a meta-analysis done by Legris et al. (2003) has suggested that attitude does not mediate the influence of perceived usefulness or perceived ease of use on either the usage or the behavioral intention to use technology in general. The second reason is the need to keep the research model focused on the more theoretically relevant factors.

CONCLUSION

This research built on the limitations of the TAM as a tool that does not capture key factors such as the risk and trust involved in mobile banking adoption. It postulates that technology readiness, which encompasses optimism, innovativeness, discomfort, and insecurity, will have direct positive and negative impacts on people's trust in mobile banking. It also distinguishes between the two types of social influences (subjective norms and critical mass) associated with technology adoption in the IS literature. Like previous studies, this study considers the direct impact of *perceived critical mass* on people's intention to use mobile banking, but unlike previous studies, the study introduced an indirect impact that *perceived critical mass* may also have through its interaction with perceived usefulness and perceived ease of use.

Although explicit prescriptions should await empirical support for the propositions, the research model and the supporting literature suggest some potential theoretical and practical implications. In particular, if it turns out to be conclusive, the testing of the interaction effects of *perceived critical mass* may provide some ground for financial institutions offering mobile banking to revisit their marketing effort in a way that may help widen their mobile banking customers' base.

References

Ajzen, I. (1991). The theory of planned behavior. *Organizational behavior and human decision processes, 50*(2), 179-211.

Amin, H. (2007). Internet banking adoption among young intellectuals. *Journal of Internet Banking & Commerce, 12*(3), 1-13.

Ayers, D. J., Menachemi, N., Ramamonjiarivelo, Z., Matthews, M., & Brooks, R. G. (2009). Adoption of electronic medical records: The role of network effects. *Journal of Product & Brand Management, 18*(2), 127–135. doi:10.1108/10610420910949022

Barki, H., & Hartwick, J. (1994). Measuring user participation, user involvement, and user attitude. *MIS Quarterly, 18*(1), 59-82. doi:10.2307/249610

Chiou, J. -S., & Shen, C. -C. (2012). The antecedents of online financial service adoption: The impact of physical banking services on Internet banking acceptance. *Behaviour and Information Technology, 31*(9), 859-871. doi:10.1080/0144929X.2010.549509

Cho, H. (2011). Theoretical intersections among social influences, beliefs, and intentions in the context of 3G mobile services in Singapore: Decomposing perceived critical mass and subjective norms. *Journal of Communication, 61*(2), 283-306.

Davis, F. D. (1989). Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS quarterly, 13*(3), 319-340.

Doney, P. M., & Cannon , J. P. (1997). An examination of the nature of trust in buyer-seller relationships. *Journal of Marketing, 61*(2), 35-51.

Elliott, K. M., Meng, J., & Hall, M. C. (2008). Technology readiness and the likelihood to use self-service technology: Chinese vs. American consumers. *Marketing Management Journal, 18*(2), 20-31.

Fishbein, M., & Ajzen, I. (1975). *Belief, attitude, intention and behavior: An introduction to theory and research.* Reading, Mass. : Addison-Wesley Pub. Co.

Fox, S. (2013, August 7). *51% of U.S. Adults Bank Online*. Retrieved from Pew Research Center: http://www.pewinternet.org/2013/08/07/51-of-u-s-adults-bank-online/

Grabner-Kraeuter, S. (2002). The role of consumers' trust in online-shopping. *Journal of Business Ethics, 39*(1-2), 43-50.

Griskevicius, V., Goldstein, N. J., Mortensen, C. R., Cialdini, R. B., & Kenrick, D. T. (2006). Going along versus going alone: When fundamental motives facilitate strategic (non) conformity. *Journal of personality and social psychology, 91*(2), 281-294.

Homburg, C., Wieseke, J., & Kuehnl, C. (2010). Social influence on salespeople's adoption of sales technology: A multilevel analysis. *Journal of the Academy of Marketing Science, 38*(2), 159-168. doi:10.1007/s11747-009-0157-x

Karahanna, E., & Straub, D. W. (1999). The psychological origins of perceived usefulness and ease-of-use. *Information & Management, 35*(4), 237-250.

Kesharwani, A., & Bisht, S. S. (2012). The impact of trust and perceived risk on internet banking adoption in India: An extension of technology acceptance model. *International Journal of Bank Marketing, 30*(4), 303–322. doi:10.1108/02652321211236923

Kraut, R., Patterson, M., Lundmark, V., Kiesler, S., Mukophadhyay, T., & Scherlis, W. (1998). Internet paradox: A social technology that reduces social involvement and psychological well-being? *American Psychologist, 53*(9), 1017–1031. doi:10.1037/0003-066x.53.9.1017

Legris, J. Ingham, P. Collerette (2003). Why do people use information technology? A critical review of the technology acceptance model, Information & Management, 40, 191–204

Lou, H., Luo, W., & Strong, D. (2000). Perceived critical mass effect on groupware acceptance. *European Journal of Information Systems, 9*(2), 91-103. doi:10.1057/palgrave.ejis.3000358

Mayer, R. C., Davis, J. H., & Schoorman, F. D. (1995). An integrative model of organizational trust. *Academy of Management Review, 20*(3), 709-734.

McKechnie, S., Winklhofer, H., & Ennew, C. (2006). Applying the technology acceptance. *International Journal of Retail & Distribution Management, 34*(4), 388–410. doi:10.1108/09590550610660297

Mustonen-Ollila, E., & Lyytinen, K. (2003). Why organizations adopt information system process innovations: A longitudinal study using Diffusion of Innovation theory. *Information Systems Journal, 13*(3), 275-297. doi:10.1046/j.1365-2575.2003.00141.x

Parasuraman, A. (2000). Technology Readiness Index (TRI): A multiple-item scale to measure readiness to embrace new technologies. *Journal of Service Research, 2*(4), 307–320. doi:10.1177/109467050024001

Roca, J. C., García, J. J., & de la Vega, J. J. (2009). The importance of perceived trust, security and privacy in online trading systems. *Information Management & Computer Security, 17*(2), 96-113. doi:10.1108/09685220910963983

Rogers, E. M. (1995). *Diffusion of innovations* (4th ed.). New York: Free Press.

Schmitz, J., & Fulk, J. (1991). Organizational colleagues, media richness, and electronic mail: A test of the social influence model of technology use. *Communication Research, 18*(4), 487–523. doi:10.1177/009365091018004003

Shen, Y. C., Huang, C. -Y., Chu, C. -H., & Hsu, C. -T. (2010). A benefit–cost perspective of the consumer adoption of the mobile banking system. *A benefit–cost perspective of the consumer adoption of the mobile banking system, 29*(5), 497–511. doi:10.1080/01449290903490658

Singer, D. D., Baradwaj, B. G., Flaherty, S., & Rugemer, F. (2012). The frequency and intensity of experience in online banking use. *Journal of Internet Banking & Commerce, 17*(1), 1-22.

Sledgianowski, D., & Kulviwat, S. (2009). Using social network sites: The effects of playfulness, critical mass and trust in a hedonic context. *Journal of Computer Information Systems, 49*(4), 74-83.

Strader, T. J., Ramaswami, S. N., & Houle, P. A. (2007). Perceived network externalities and communication technology acceptance. *European Journal of Information Systems, 16*(1), 54–65. doi:10.1057/palgrave.ejis.3000657

Teo, T. (2010). A path analysis of pre-service teachers' attitudes to computer use: Applying and extending the technology acceptance model in an educational context. *Interactive Learning Environments, 18*(1), 65-79. doi:10.1080/10494820802231327

Vatanasombut, B., Igbaria, M., Stylianou, A. C., & Rodgers, W. (2008). Information systems continuance intention of web-based applications customers: The case of online banking. *Information & Management, 45*(7), 419–428. doi:10.1016/j.im.2008.03.005

Venkatesh, V., & Davis, F. D. (2000). A theoretical extension of the technology acceptance model: Four longitudinal field studies. *Management science, 46*(2), 186-204. doi:10.1287/mnsc.46.2.186.11926

Wang, S. W., Hsu, M. K., Pelton, L. E., & Xi, D. (2014). Virtually compatible or risky business? Investigating consumers' proclivity toward online banking services. *Journal of Marketing Channels, 21*(1), 43–58. doi:10.1080/1046669x.2013.832466

Wang, Y. -S., Wang, Y. -M., Lin, H. -H., & Tang, T. -T. (2003). Determinants of user acceptance of Internet banking: An empirical study. *International Journal of Service Industry Management, 14*(5), 501–519. doi:10.1108/09564230310500192

Yu, C. (2012). Factors affecting individuals to adop mobile banking: empirical evidence from the UTAUT model. Journal of Electronic Commerce Research, 3(2), 104-121.

Zhu, J. H., & He, Z. (2002). Perceived characteristics, perceived needs, and perceived popularity: Adoption and use of the Internet in China. *Communication Research, 29*(4), 466–495. doi:10.1177/0093650202029004005

SUPPORT FOR THE INCLUSION OF PERSONAL VALUE PREFERENCES IN DECISION SUPPORT SYSTEMS

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ABSTRACT

We consider the important issue of including personal value preferences in decision support systems (DSS). Various personal differences have been shown to affect the acceptance, use, and effectiveness of DSS. Decision-making models offer a theoretical basis for the inclusion of various personal differences (including personal value preferences) in decision-making. Research in the field of psychology has long recognized the importance of values in both motivation and choice behavior. Other research has also found personal values to be relevant in decision-making. We posit that since personal values are important in the decision-making process, they should also be important in the support of decision-making and thus in decision support systems.

KEY WORDS: personal values, value types, decision, decision model, decision making, decision support systems, user expectations

DATA AVAILABILITY: please contact authors

SUPPORT FOR THE INCLUSION OF PERSONAL VALUE PREFERENCES IN DECISION SUPPORT SYSTEMS

Introduction

We posit that personal values and value types are important in decision-making and therefore should be considered relevant to the study of Decision Support Systems (DSS). We describe this relationship and relevance in detail. For example, a cancer patient may have several options and her personal values may eliminate certain treatments, based on probabilities of success, general health, or age; while others may involve religious values that prohibit certain treatments. Friends of two authors observed strictly kosher religious dietary laws. When their initially prescribed breast cancer medication involved orally ingesting medicine derived from swine, they sought, discovered, and were treated with comparable injection treatments.

This paper is organized as follows: First, literature related to various personal differences and DSS is briefly reviewed. Second, personal difference psychology, the importance of values to human choice behavior, and research regarding values and value types are discussed. Third, we

discuss decision-making models followed by sections describing individual difference psychology, values and personal values, and decision-making. Fourth, in the final section, we provide a detailed discussion which includes our conclusion.

Personal Differences and Decision Support Systems

The relationship between the field of personal difference psychology and Decision Support Systems (DSS) is not directly addressed in the literature. However, a relationship between this field of study and decision support systems can strongly be inferred from the importance given in the literature to various factors that can be considered personal trait related: (1) intuition, (2) cultural differences, (3) problem solving modes, (4) cognitive style, (5) human factors, and (6) personality type. We review each of these in turn.

Intuition

Little (1970) indicated that in order for management science models to be useful, they must be used. Instead of designing models for the "technical people," they should be personalized to the user. "The model is meant to be a vehicle through which a manager can express his views about the operations under his control … the whole process might be described as an updating of his intuition." Sauter (1999) describes six forms of intuition (illumination, detection, evaluation, prediction, operative, and creative) and their implications for decision support systems. These implications include virtual experience, tracking experience, data mining, tools for analysis, and presentation.

Intuition is improved by experience. By enabling managers to have virtual experience and track their own experiences, a DSS can encourage intuition. In addition, intuition is facilitated by the availability of data mining for scanning of relevant data, tools that ease the identification, summarization, and analysis of data, and presentation modes that illuminate trends (Sauter, 1999). An interesting suggestion by Sauter (1999) to improve the intuitive support of DSS is the development of private databases. These secure databases could be used to store decision-maker specific information: ethics, values, goals, plans, past experiences, etc. "Allowing DSS users to enter this information into the system or allowing the system to deduce relevant factors based on past decisions could facilitate intuition" (Sauter, 1999). In general, some active form of artificial intelligence would be necessary for the latter to work successfully.

The importance of combining intuition with decision support models was addressed by Blattburg and Hoch (1990). They compared the results of five different business forecasts made by managers without model support, made by the model without manager input (intuition), and business forecasts made with a combination of manager intuition and the model. The results indicated that the combination of the model and the manager's intuition improved performance by about 16%. Additional evidence of the importance of intuition to DSS was found as a byproduct of a study by Lu, Yu and Lu (2001) of the acceptance of the three different DSSs based on cognitive style. While the results for cognitive style differences were mixed (the acceptance of only one of the three DSSs was found to be based on cognitive style), there was a significant indication

regarding trust. When given a choice among the decision results of the three models and intuition, the subjects (MIS graduate students) picked the intuitive decision approximately 90% of the time. There are instances when a decision needs to be made quickly without the benefit of adequate planning, funding or information. Turban, Aronson, Liang and Sharda (2007) refer to this type of intuitive decision-making as decision making from the gut:

> *Many analysts and reporters characterize this gut-based decision-making process as the brilliance of a leader who quickly synthesizes situational information from his analysts to make an informed decision, while others attribute this behavior to a lack of understanding of the facts and analysis, possibly based on laziness.*

By contrast, Sadler-Smith and Shefy (2004) argue that intuition is an integral part in the executive decision-making processes. They propose an integrated approach where "intuition and rationality are complementary to the extent that executives need to be able to learn how to use each to fit the demands of particular decision-making situations." This study also provides a series of guidelines that acknowledge the limitations in the use of intuition while emphasizing the effective and intelligent use of it. Executives are therefore required to expand their repertoire of skills and strategies beyond rational analysis and include intuitive judgment possibly through training and coaching. Intuition should be regarded as a natural and frequent component in decision-making. When explained and managed effectively, intuitive intelligence can help managers make both fast and accurate decisions in the constantly changing business environments (see also Hodgkinson, Langen-Fox, & Sadler-Smith, 2008; and Hodginson, Sadler-Smith, Burke, Claxton, & Sparrow, 2009). The enhanced speed and accuracy in the decision-maker's abilities are also attributed to intuitive intelligence in the work of Dane and Pratt (2007) and Miller and Ireland (2005). The Dane and Pratt (2007) study defines the conditions for using intuition in decision-making. They state that accurate intuitive judgments can only be generated by an executive who is an expert in that specific field or industry from which the cognitive schemas were developed. In turn, this argument limits the transferability of intuitive skills across fields and industries. Apart from strategic decisions, the allure of intuitive decision-making and its constraints is also observed in using moral intuition and ethical decision-making (Sonenshein, 2007).

Cultural Differences

Tai and Phelps (2000) compared the perceptions of Hong Kong CEO's and CIO's with respect to their vision of information technology (IT), the importance placed on IT issues, their acceptance of IT for knowledge management, and the effect of CEO/CIO relationships. In addition, the study included CEO's and CIO's from both Western and Chinese firms. It was hypothesized that there would be a perceptible gap between IT perceptions of CEO's and CIO's based on national culture, type of industry, and management relationship. Contrary to prior research, their "…study suggests that overall there is no significant difference between CEO and CIO perceptions of IT visions, organizational IT issues, or the use of IT for KM." In connection with implementing knowledge management, the respondents from both groups viewed the importance of people, process, and technology the same. In addition, there was some evidence that "…poor CEO/CIO relationships may adversely affect similarity of perceptions." The main

perception differences identified were culturally oriented. While the Western CEO's and CIO's showed no mean difference in scores, their Chinese counterparts showed "…a significant difference in mean scores for 'vision to transform'… and in rankings…" between the CEO's and CIO's in their perceptions of the role played by Information Technology: that is, whether the role of IT is management information focused (referred as 'informate up') or employee improvement focused (referred to as 'informate down'). "Chinese firm CEO's ranked 'informate up' first and 'informate down' last on the list." Tai and Phelps (2000) indicate that this difference most probably reflects the Chinese view of information as being personally rather than organizationally owned. Also, top Chinese managers maintain control by storing critical information in soft form instead of collectively accessible organizational form. This control-oriented cultural difference can impede the implementation of knowledge management systems.

Therefore, they point out that the personal trait of "power" may possibly have cultural implications. This potential cultural difference could apply not only to the acceptance of knowledge management systems, but possibly also to the acceptance and utilization of decision support systems.

A more recent study by Tihanyi, Griffith and Russell (2005) examines cultural distance as a factor in multinational corporations' decisions relating to entry mode choice, level of international diversification and performance. While the effect of cultural distance is not unidirectional throughout the sample, the evidence suggests that cultural distance does interfere in the decision-making process. Similarly, cultural sensitivity is a determining factor when dealing with a foreign trading partner. This factor is crucial in negotiations, expansion decisions and in the training of new buyers (Tihanyi, et al., 2005).

Problem Solving Modes

Wierenga and Van Bruggen (1997) used four problem-solving modes (optimizing, reasoning, analogizing, and creating) to develop an integrated framework with marketing management support systems (MMSSs). Their framework was an attempt "...at transforming decision situations, through marketing problem solving modes (MPSMs), into requirements for decision support. By doing so, the MMSS that fits best with the decision situation can be determined." In discussing the framework, they indicated a belief "...that managers will be inclined to use only MMSSs that match with the MPSM they use" (Wierenga & Van Bruggen, 1997).

The relationship between decision support systems and problem solving modes was expanded by Van Bruggen and Wierenga (2001) in their study of the demand for Management Support Systems (MSS, i.e., DSS) and the supply of appropriate support systems. "The premise of this study is that in order to be successful, Management Support Systems (MSS) should match the thinking and reasoning processes of managers." The supply should match the demand. The supply side factors were identified as composed of 44 MSSs in the field of marketing divided, based on like characteristics, into eight Marketing Management Support Systems (MMSS). The demand side factors were identified as composed of four problem-solving modes used by managers in decision-making.

The results of this study indicate that there is often a mismatch between the supply of MMSSs and the problem-solving mode. It was found that a match existed between the demand for support and the support actually offered in only thirteen cases out of a total of thirty-four situations for which data were available. In comparison with bad matches, good matches between the decision-making mode and the MMSS characteristics result in greater user satisfaction, a greater impact on decision making, and higher company implementation and retention of the system.

Cognitive Style

The importance of considering cognitive style when designing a DSS has been a topic of debate for over thirty years. In 1980 Sprague referenced the idea of using cognitive style when he suggested using "...a DSS in a way that reveals what managers can and should receive from an information system. For example, one of Scott Morton's early suggestions was that the system be designed to capture and track the steps taken by managers in the process of making key decisions..." Benbasat and Taylor (1982) specifically referenced cognitive style in the design of management information systems:

> *Systematic (and thinking) decisionmaker types would prefer decision aids and reporting systems which are quantitative in nature with results supported by mathematical formulas. Intuitive decisionmakers would require more data search capabilities prior to reaching decisions... The information system should give them capabilities to try alternative solutions and analyze the possible outcomes before they decide on their final approach to solving the problem.*

Huber's (1983) study reached two conclusions that questioned the use of cognitive style in the design of DSSs: "…[first] the currently available literature on cognitive styles is an unsatisfactory basis for deriving operational guidelines for MIS and DSS designs. …[and second], further cognitive style research is unlikely to lead to operational guidelines for MIS and DSS designs." He went on to state the following:

> *Whether the user's numerical score on a marginally predictive cognitive style assessment instrument would be of much value to either the user or the designer/consultant seems highly problematic. Instead, it seems that task considerations and the user's expressed preferences for specific DSS features should be the factors that determine the DSS design.*

Despite Huber's concern about the use of cognitive style research in developing guidelines for DSS design, research into this area continued. A study by Van Bruggen, Smidts and Wierenga (1998) compared the benefits derived from a Marketing Decision Support System (MDSS) based on cognitive style as measured along the dimensions of low-analytical and high-analytical. The results of their laboratory experiment indicated that the high-analytical decision-makers generally outperformed the low-analytical decision-makers. The high analytic types showed more variation in their decisions, showed a greater ability to identify key variables, and made better decisions. However, the low-analytical decision-makers did make better decisions with the aid of the MDSS than without it – an implication that "…in companies low-analytical decision-makers should also be provided with these systems and convinced of their usefulness."

Barkhi (2002), in a study of cognitive style related to communication mode, referenced six research studies related to cognitive style and decision-making between 1986 and 1999. He concluded that "...there is evidence that [cognitive style] explains decision choices, preferences, and perceptions." Prior literature has documented the significant effect of cognitive style on group decision-making. Franco and Meadows (2007) extend the analysis and examine the impact of cognitive style on the problem structuring methods (PSMs). The study identifies and explores the role of four different cognitive style functions in problem structuring interventions. From another perspective, Armstrong and Hird (2009) examine the relation between cognitive style and entrepreneurial drive. Their empirical evidence suggests that entrepreneurs tend to be more intuitive and less analytic than non-entrepreneurs. In addition, more intuitive entrepreneurs display higher levels of entrepreneurial drive which implies that intuition and cognitive style can predict successful entrepreneurs and therefore better decision makers.

Human Factors

Due to the increase in competition problems in the mature legal market, the European Union funded trials of a new Legal Support System (LSS) in three London law firms. Hayman and Elliman (2000) present a case study of the problems encountered in the implementation of a LSS in one of the law firms. This system aimed at reducing many of the tedious manual functions encountered in storing, retrieving, recording, copying, analyzing, and preserving the chain of evidence of legal documents. The new "…system design sought to provide support for browsing and concept formation by including optical character recognition and free text retrieval interfaces within the system." Document management was to be improved by use of encoding-methods and full-text search methods and by elimination of filing and copying. However, the LSS system design did not adequately address the human factors of these knowledge workers. While it did automate processes, it did not provide the needed holistic approach to core and informing activities.

Because of the perceived need to be accountable and control the evidence, the Solicitor (an attorney who advises clients on legal matters, represents clients in certain lower courts, and prepares cases for barristers to present in the higher courts) did not trust the biographical coding by subordinates and stopped using juniors for research (he accessed the system directly). This resulted in his doing many menial tasks and becoming insulated from his support staff. Consequently, the juniors lost track of the progress of the case. In addition, while the automated system was used for document retrieval, it was not used for idea exploration and generation. The knowledge work was performed by skimming and reading the hard copies maintained in binders. As stated by Hayman and Elliman (2000), "the system's intent, to remove some of the apparently tedious document handling tasks, was counter productive as it inhibited the Solicitor in becoming familiar with the breadth and richness of the documentation." This case study points out the need for the computerized support system to support certain human factors in order to be accepted and used. These factors include accommodating individual differences in knowledge acquisition (core and informing activities), the reliance on and acceptance of the work of fellow employees, and the sharing of information. These three factors could also be associated with the individual differences of cognition, trust, and power.

Prior research (e.g., see Turban, et al., 2007) suggests that when a new information system is developed or an existing one is modified, user involvement and user training are critical to its use and ultimately its success. It is through user involvement in the development process that the actual work processes (including the human factors) are analyzed and understood and improved upon by the development team.

Personality Type

The Swiss psychologist Carl G. Jung theorized that a person's mental habits could be described by three psychological dimensions: energy, perceiving, and evaluation. Each of these three dimensions is bipolar. Energy is divided into extraversion and introversion; perceiving is divided into sensing and intuition; and, evaluation is divided into thinking and feeling. These theorized dimensions were later operationalized by the Myers-Briggs Type Indicator (Pearman & Albritton, 1997). Mason and Mitroff (1973) point out that in the Jungian System most individuals adopt "…a preference for one mode of perceiving (sensation or intuition), and one mode of evaluation (thinking or feeling). The alternative modes remain, as a result, undeveloped or unconscious." The individual's preference for a perceiving mode affects the type of information favored by that individual: sensing types favor sensory data while the intuition types favor abstract data. The individual's preference for an evaluation mode affects the individual's preference for a decision or judgment mode: Thinking types favor cause-and-effect type analysis while feeling types favor decisions based on personal values (Pearman & Albritton, 1997).

Therefore, both the information preferred by a decision-maker and the decision mode is related to that individual's psychological type. According to Masson and Mitroff (1973),

> *What is information for one type will definitely not be information for another. Thus, …designers of MIS [should not force] all types to conform to one [type of information], but …give each type the kind of information he is psychologically attuned to and will use most effectively.*

Managers' personality and their ability to influence others do affect their success in decision-making (Yukl, 1998). This is a crucial factor since managers who use pressure and persistence may influence the decision process differently than managers who arrive at decisions through constructive cooperation. Cable and Judge (2003) examine the theoretical linkages between the five-factor model of personality and managers' influence tactic strategies. The study concludes that extravert managers are more likely to use inspirational appeal and ingratiation while agreeable managers are less likely to use pressure and hard influence tactics.

The results also suggest that, while controlling for personality traits, managers choices of upward influence tactics is determined by the leadership styles. Therefore, "Managers were more likely to use consultation and inspirational appeal tactics when their supervisor was a transformational leader, but were more likely to use exchange, coalition, legitimization, and pressure tactics when their supervisor displayed a laissez-faire leadership style" (Cable & Judge, 2003). From another perspective, the study reveals that certain personality traits are common in certain job types regardless of an individual character. For example, marketing managers are more

likely to employ soft inspirational influence tactics, while finance and accounting managers are more inclined to use pressure and hard influence tactics (Cable & Judge, 2003).

In a more recent paper on the role of personal values, Illies and Reither-Palmon (2008) establish an effect of personal values on destructive leader behavior. They defined destructive behavior as a pursuit of short-term, non-value maximizing, decisions. The empirical evidence suggests that managers with self-enhancement values are more likely to make destructive decisions than individuals with self-transcendence values. Therefore, corporate value maximization is not the sole driver of decision-making. Similarly, Hemingway and Maclagan (2004) document an association between the implementation of corporate social responsibility and the various personal values of individual managers. Within the concept of managers' personality, Ivan and Ivana (2012) study provides strong evidence of interdependence between the managers' learning types - incremental and radical learning - and the strategic decision making approaches. Specifically, incremental learning has a stronger effect on analytical decision making than radical learning and consequently the managers' learning types have a significant effect in the strategic decision making outcomes.

Summary of the Personal Differences and the DSS Literature

This brief literature review points out the importance that various factors, that can be considered personal difference related, bear to the acceptance, use, and effectiveness of DSS. Sauter (1999) indicated that there are six forms of intuition, and their implications for DSS. Lu, et al. (2001) indicated a lack of trust in DSS when compared to intuition. Blattburg and Hoch (1990) showed that a combination of DSS and intuition improves results. Tai and Phelps (2000) showed that individual differences related to culture may impede knowledge management system acceptance. Van Bruggen and Wierenga (2001) found a mismatch between the demand for marketing management support systems based on problem solving mode and the supply of support. Van Bruggen, et al. (1998) ascertained a difference in DSS benefit based on cognitive style. The case study of Hayman and Elliman (2000) illustrated the need for a holistic approach to LSS that included support for certain human factors. And, Mason and Mitroff (1973) explained the difference in informational needs based on different psychological types.

Decision-Making Models

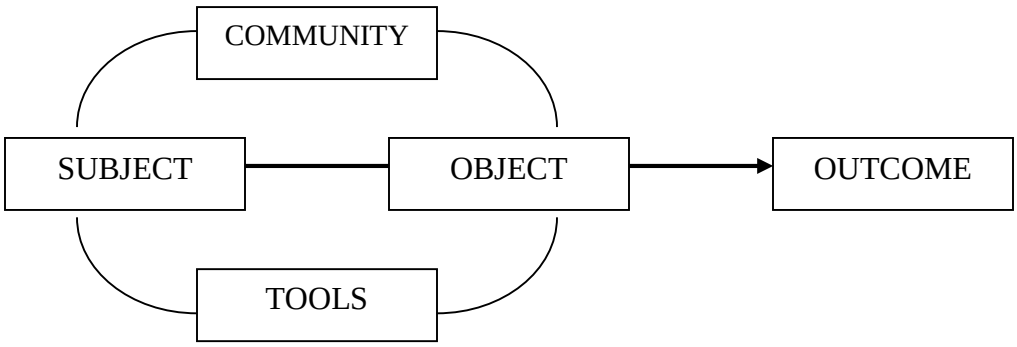
In addition to the literature support for a link between personal differences and decision-making, various decision-making models also posit this connection. We next discuss three models that demonstrate the importance of personal differences in sense-making (the ways that managers make sense of and use knowledge for decision-making), choice of reasoning made, and adoption and capability based on images. These models are the CHAT (Cultural-Historical Activity Theory) model, the ORAC (optimizing, reasoning, analogizing, and creating) model, and the image theory model.

CHAT Model

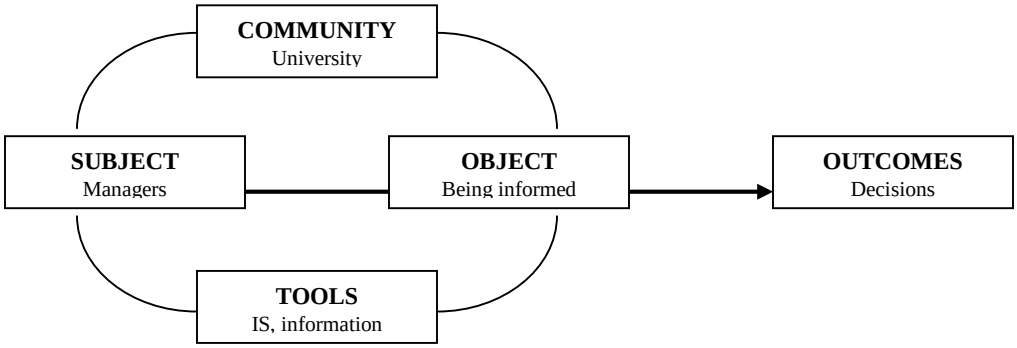
The Cultural-Historical Activity Theory (CHAT) Model (Figure 1) for management support systems recognizes the computer as a tool that mediates decisions and activity. In this model, the sense-making connections between the information supplied by the computerized information system and the actual decision are a cognitive function of the manager (Hasan & Gould, 2001). While traditional decision support research is based on the rational model where a structure exists for finding an optimal solution, most senior management decision-making is not completely rational and is made in an unstructured environment. Such unstructured decisions are usually supported by an organizational information system. A sense-making activity provides the cognitive link between the information and the decision. This sense-making activity is based on "…each manager's perceptions [being] …colored by experience, values, and motives" (Hasan & Gould, 2001). Hasan and Gould (2001) proposed that the Cultural-Historical Activity Theory (CHAT) provides the appropriate theoretical basis for linking knowledge management support, sense-making, and strategic decision-making. "This theory provides a practical model of what people do, focusing on the relationship between the subject and object of an activity, a relationship mediated by tools and community" (Hasan & Gould, 2001).

FIGURE 1
The CHAT Framework

The CHAT framework of an activity



The CHAT framework applied to the sense-making activity of managers



Adapted from Hasan and Gould (2001)

The CHAT Model recognizes three kinds of tools: primary, secondary, and tertiary. Primary tools are physical in nature and include computers. Secondary and tertiary tools are both psychological tools. Secondary tools include language, signs, ideals and models. Tertiary tools include cultural systems. Both physical and psychological tools are basic to human activity and mediate activity (Hasan & Gould, 2001).

According to Hasan and Gould (2001), "…a most important assumption in a CHAT approach is that all activity is mediated by the use of tools and by the community in which it occurs." The Internal Plan of Action (IPA) is a CHAT concept that relates to the ability of humans to manipulate representations of objects internally before taking actions in reality (Hasan and Gould, 2001). "The computer, which has been described as a cognitive artifact, can be viewed as an extension of the IPA involved in the transmission and manipulation of information" (Hasan and Gould, 2001).

In CHAT, the use of tools mediates human activities. This change in the nature of activity can also create new activities. This characteristic of tool use explains the change in work practices that is often not considered in the development of management support systems (Hasan & Gould, 2001). Therefore, the CHAT decision-making model is concerned not only with the tools provided and used by the decision-maker (data, information, knowledge, and support technology) but also with the three mediating factors of community (environment), subjects (decision-maker) and objects (sense-making activity). All three of these factors are related to personal difference psychology. The subjects have different values, morals, experiences, motives, etc. The sense-making activity relates to the individual differences in cognition. And, the effects of the community are related to behavioral differences that are influenced by nurture and to the pressures to conform to the norms of the society's values (see also Igira & Gregory, 2009).

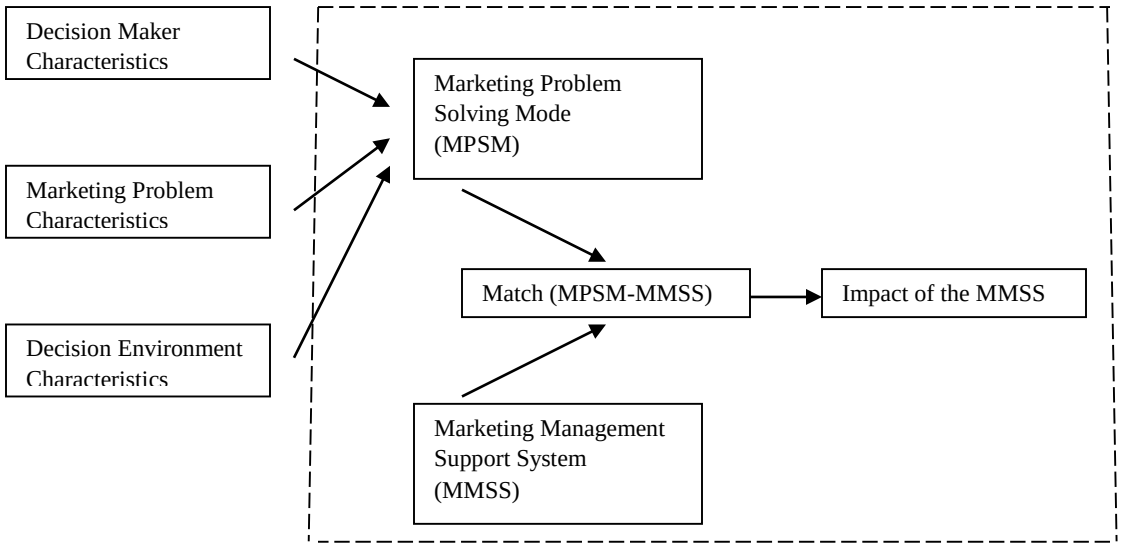
The ORAC Model

According to Van Bruggen and Wierenga (2001) four different problem-solving modes are used by decision-makers. "The specific problem-solving mode that is used depends on the characteristics of the decision-maker, the characteristics of the problem, and the characteristics of the decision environment." These four modes are identified as optimizing, reasoning, analogizing, and creating, the ORAC model (Figure 2).

In the optimizing mode the decision-maker seeks an optimal solution to a problem, often by use of a mathematical model although some problems and their concomitant solutions may be described in terms of qualitative relationships among variables. He/she seeks to find the optimal variable mix that will maximize the goal (Van Bruggen & Wierenga, 2001).

A decision-maker using the reasoning mode constructs a mental model of the problem. With important variables being chosen subjectively, mental models concerning the same decision problem will differ based on the individual characteristics of the decision-maker. Such mental models may be incomplete and may not conform to reality (Van Bruggen & Wierenga, 2001).

Figure 2
The ORAC Model



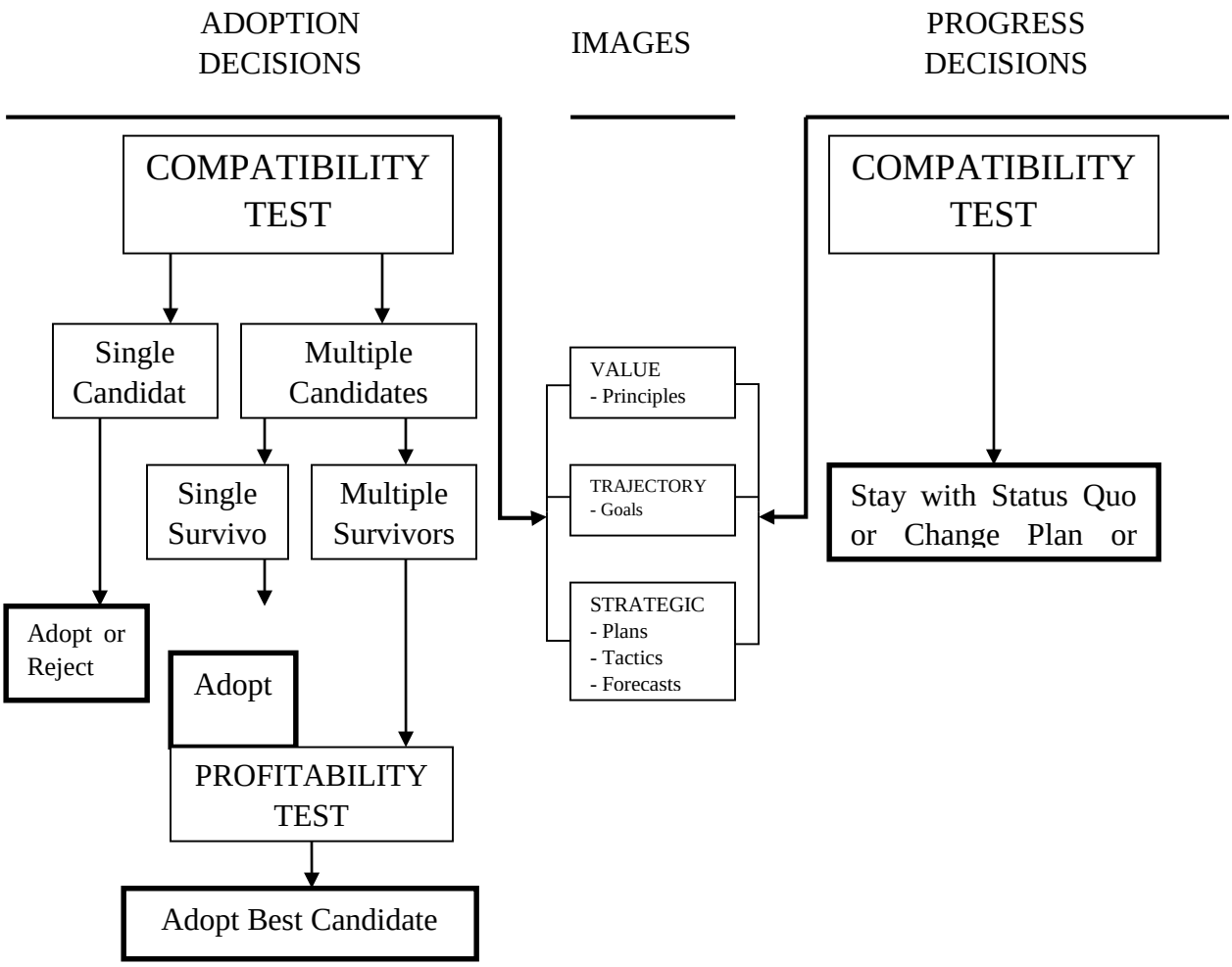
Adapted from Van Bruggen and Wierenga (2001)

The analogizing mode involves the decision-maker comparing the current decision problem to prior problems and their solutions. Mental reference is made to prior cases about which the decision-maker is knowledgeable. This reference includes recognizing the similarities and differences between the current problem and the historical case (Van Bruggen & Wierenga, 2001). Lastly, in the creating mode, the decision-maker is looking for new ideas. This process often involves thinking about a problem in a different way (outside the box) and formulating and exploring novel and multiple solutions (Van Bruggen & Wierenga, 2001). These four modes may be used independently or together in the decision process. However, the choice of mode and when to use it are driven by the decision-maker, the problem, and the environmental characteristics. Therefore, this model recognizes the personal traits of the decision-maker as one of the "drivers" in the decision process (See Wierenga (2010) for a recent application of the ORAC model).

Image Theory Model

The Image Theory Model (Figure 3), as posited by Mitchell and Beach (1990), includes the key concepts of images, decisions, tests, and frames. Images are of three types: principles, goals, and plans. Decisions are of two types: progress and adoption. Tests include compatibility and profitability. And, frames refer to the circumstances surrounding a decision.

Figure 3
Image Theory Diagram



Adapted from Beach and Mitchell (1990)

The three types of images (principles, goals, and plans) form the set of standards that are used by the decision-maker in admitting alternatives to the decision set. Principles are composed of the "values, morals, and beliefs" that give direction to the decision-maker. Goals represent the decision-maker's aspirations for the future and plans represent the strategy adopted by the decision-maker to achieve his/her goals. Image theory posits that these three images form the template that is used by the decision-maker in making the progress or adoption decision (Mitchell & Beach, 1990). The progress decision involves the decision-maker's monitoring of progress towards goals and the continued compatibility fit with the three images.

> *If it fits, if the disparity between its attributes and the images does not exceed a threshold value, called the rejection threshold, and if no other competing candidates also fit, it is adopted. If not, it is rejected. Either way, decision-making is seen as terminating. (Mitchell & Beach, 1990).*

At this step, a decision is made as to whether or not to continue with the current plans and goals. While the progress decision is focused on the "fit" (all or none) of goals and plans with images, the focus of the adoption decision is on profitability. Once more than one member qualifies to be included in the decision set based on compatibility with the three images, the decision-maker must use some strategy to compare the relative merits of each member (Mitchell & Beach, 1990). Mitchell and Beach (1990) define framing as the decision-maker's ability to use past experience – both successes and failures – as the context for current decision-making. By comparing the current decision problem to similar prior circumstances (problems and their solutions), the decision-maker is able to augment the available data and information. "The theory posits that the context in which decisions occur gives them meaning."

From the perspective of the Mitchell and Beach's (1990) Image Theory Model, the focal point of decision-making involves the determination of the "fit" with the images of the decision-maker. If the decision alternatives are not compatible with the individual decision-maker's value image, goal image, and plan image, it will be rejected. While goals and plans may be changed in the adoption decision phase, the value image is seen as remaining constant. The theory "…states that decision-makers adopt and implement plans to reach goals in order to satisfy principles" (Mitchell & Beach, 1990). Therefore, Image Theory appears to view decision-making as value driven.

Summary of Models

The three decision models, briefly described above, all emphasize the importance of personal traits in decision-making. The CHAT model identifies the personal characteristics of the decision-maker as one of three mediating factors in the use of knowledge, data, information, and technology (Hasen & Gould, 2001). The ORAC model of decision modes emphasizes the importance of the personal characteristics of the decision-maker in the choice of mode (Van Bruggen & Wierenga, 2001). Whereas, the Image Theory Model stresses the importance of the compatibility of the decision set alternatives with the principles, goals and plans of the decision-maker. This theory views decisions as initially values-driven (Mitchell & Beach, 1990).

Individual Difference Psychology and Values

Person-Environment (P-E) Fit Theory posits that human behavior is a function of personal variables (nature), environment variables (nurture), and the interaction of these two variables. In studying person variables, individual difference psychology has traditionally concentrated on the person variable of ability and the two motivational variables of interest and personality traits. However, while ability is a good predictor of performance, the motivational factors only add incremental validity (Dawis, 1999).

Dawis (1999) proposes that personal values be added to abilities, interest, and personality traits as a predictor of behavior. Her nomination of values as an important person variable is made based on evidence indicating a relatively small correlation with and variance overlap with the other three variables. In addition, in stating the importance of values to choice behavior, Dawis (1999)

states that "choice involves judgment, and judgment implies values. Choice may also involve reasoning. Whether we reason from first principles to conclusions or (as we more frequently do) choose our conclusions first then reason back to the appropriate first principles, we choose our conclusions and first principles on the basis of values."

In addition to the P-E Fit Theory of behavior, attitudes have been studied as indicators of social behavior. Rokeach (1968), however, showed that personal values were better than attitudes as predictors of behavior. He states that "…a value, unlike an attitude, is a standard or yardstick to guide actions, attitudes, comparisons, evaluations, and justification of self and others" (Rokeach, 1968). Rokeach (1968) identified 18 instrumental and 18 terminal values that had a 0.70 test-retest reliability to both behavior and attitudes. These two systems of values were defined by Rokeach as follows:

> *An instrumental value is … defined as a single belief which always takes the following form: I believe that such-and-such a mode of conduct (e.g., honesty, courage) is personally and socially preferable in all situations with respect to all objects. A terminal value takes a comparable form: I believe that such-and-such an end-state of existence (e.g., salvation, a world of peace) is personally and socially worth striving for.*

Schwartz and Bilsky (1987) expanded the work performed by Rokeach (1968). Based on a smallest space analysis of cross-cultural data collected from subjects in Germany and Israel, they mapped thirty-six values according to eight domains. These domains were then identified as to two levels of interest (individualistic vs. collectivist) and two goals (terminal vs. instrumental). Subsequent work by Schwartz and Sagiv (1995) expanded the theory of the content and structure of human values. In this cross-cultural study of 88 samples from 40 countries, 56 values were tested. The results indicated that the 56 values mapped into ten value types that represented four bipolar dimensions. The instrument they developed – The Schwartz Value Survey – is now "…the most widely used instrument for measuring personal values" (Giacomino & Akers, 1998).

Personal Values and Decision-Making

The personal values of individuals have been shown as related to various aspects of decision-making. The following selected literature review is illustrative of this relationship.

The personal values of American managers seem to be stable over time. In a 1984 study of manager values, Posner and Schmidt (1984) identified over 255 different manager values and traits. The value of integrity tops the list in importance. Posner and Schmidt (1992), in an updated study in which over 1,000 managers responded to a values survey, found that the value of integrity was still the number one value followed by competence. They stated that "managers today, like their colleagues surveyed a decade ago, hold in highest regard people who are seen as honest, and competent" (Posner & Schmidt, 1992). In addition to the stability of manager values, Posner and Schmidt (1992) indicated their perceived importance of values to management decision-making. They stated that "…values determine which facts we examine with care and which we pass over; which options for action we look upon with favor from the start and which we reject out of hand." This indicates that values directly influence the emphasis that a manager places on the factors involved in the decision and the decision-making process.

Oliver (1999) studied the personal value structure of corporate managers over three decades. He found that the structure of values indicated by value groupings had not changed over the thirty-year period. In addition, the study found support for differences between personal and corporate value systems. He stated that "if this suggestion is correct, there is evidence to support expectation of different decision-making paradigms between personal and corporate environments."

Dunbar, Saiz, Stela and Saez (2000) used the Schwartz Values Survey (Schwartz & Sagiv, 1995) to study in-group/out-group bias. They found that the perceived difference in values between two groups were predictive of negative stereotyping. Therefore, a perception of value difference between groups can predict decisions relating to bias and stereotyping.

The relationship between work values and decision-making was studied by Ravlin and Meglino (1981). They compared the values of 103 undergraduate students using four different values measurements to the results of twenty work-related decisions. The result indicated that the subjects made decisions that were in agreement with their values. They stated that "values were also found to be a guide or standard for decision-making. In addition to its theoretical significance, this finding has profound implications for organizations that desire decisions to be reflective of particular patterns of values."

Korsgaard, Meglino and Lester (1996) investigated the relationship between the value "concern for others" and decision-making. Their study "…indicated that individuals high in concern for others were less attracted to the payoffs of various decision options and were less discerning about different payoffs and risks associated with these options." They theorized that this value difference may be predictive of decision-making and stated that "…these findings suggest that concern for others may predict basic differences in a variety of judgment and decision-making situations."

Values that are traditionally considered related to Asian cultures and that are indicative of uncertainty avoidance were studied by Robertson and Hoffman (2000). The results of their study of 255 upper-level undergraduate business students indicated that these values were also commonplace in the U.S. In discussing the management implications of their study, they stated that "managers should focus on the value set of each individual when developing policies and determining who should deal with certain foreign trade partners."

The results of a pilot study of oncologist and treatment acceptance decisions in a hospital in Amsterdam were presented by Huijer and Van Leeuwen (2000). While the doctors made their cancer treatment decisions based solely on the medical pros and cons, patients weighed the medical treatment advised in conjunction with their assessment of various personal factors. From the doctors' perspective, refusal of treatment based on non-medical grounds was viewed with disapproval, and was often explained as related to the patient having some psychological problem. Patients, on the other hand, used a different "context" than the doctors. Their context included personal circumstances, belief systems, values, emotions, and attitudes. With "one of the principles of modern cancer care [being] that it should be responsive to the patients' wishes and consistent with their values," the researchers found it "striking" that the patients' personal values were not considered by the doctors in their decision-making.

Several researchers have found a relationship between ethical decision-making and personal values. Singhapakdi and Vitell (1993) studied the ethical judgments and values of members of the American Marketing Association. They found that the values of self-respect and being well respected had high correlations with ethical judgment while the values of sense of accomplishment and excitement were predictors of unethical decisions. Finegan (1994) in a study of psychology students found the value of honesty related to morality judgments while the value of ambition predicted behavior. And, Fritzsche (1995) in a study of values of marketing managers and four ethical vignettes found a difference in the instrumental and terminal values of those who would select the ethical act from those who would select the unethical act.

This limited literature review indicates a number of relationships between personal values and decision-making. Posner and Schmidt (1984, 1992) demonstrated how the personal values of managers have remained stable over time and suggested that personal values may be determinants of which facts and options are considered by the decision-maker. Oliver (1999) also found the structure of values stable and suggested a difference in decision-making paradigms between personal and corporate values. Dunbar, et al. (2000) showed perceived group values as predictors of bias. Ravlin and Meglino (1981) found that work decisions were made consistent with personal values. Korsgaard, et al. (1996) identified a relationship between the value of concern for others and the cost/benefit analysis of decision options. Robertson and Hoffman (2000) found Asian cultural values to be commonplace in the U.S. and suggested that these values be considered in decisions involving foreign trade. Huijer and Van Leeuwen (2000) pointed out that oncologists need to consider patient values when choosing treatments. And, Singhapakdi and Vitell (1993), Finegan (1994), and Fritzsche (1995) all demonstrated a relationship between ethical decision-making and various personal values.

Discussion

Research has indicated a relationship between the acceptance, use, and effectiveness of decision support systems and various factors that can be identified as personal difference related. Models of decision-making also emphasize personal related factors such as sense-making, the selection of decision-making mode and images. In all three of the models cited, the personal values of the decision-maker are deemed important.

Research shows that a person's values are important in the study of choice behavior (Dawis, 1999). Based on the works by Rokeach (1968), Schwartz and Bilsky (1987), and Schwartz and Sagiv (1995), a number of personal values have been validated and shown to "form a system of compatible and conflicting motivations…"(Schwartz & Sagiv, 1995). Subsequent values research has indicated a number of relationships between personal values and decision-making. With "…the central purpose of DSS (being) to support and improve decision-making" (Turban, et al., 2007) and the values of the decision-maker shown as, in many instances, critical to the decision process, we suggest that further research into the relationship between decision support systems and values and value types be pursued. For example, questions such as these merit additional study: Can the consideration of values be used to improve the type of system offered to users with particular decision-making modes? Will the addition to DSS of a private and secure database that

includes personal values improve the intuition support of DSS? How do the personal values of the user affect the acceptance of a DSS? Can the consideration of values improve the trust in DSS assisted decisions? And, will the acceptance and use of DSS be improved by the consideration of various cultural value related factors? As values and value types are included in Decision Support Systems, further questions expanding their decision-making capabilities will result.

REFERENCES

Armstrong, S. J. & A. Hird (2009). Cognitive Style and Entrepreneurial Drive of New and Mature Business Owner-Managers. *Journal of Business and Psychology*, 24 (4), 419-430.

Barkhi, R. (2002). Cognitive style may mitigate the impact of communication mode. *Information and Management,* 39 (8), 677-688.

Benbasat, I. & R.N. Taylor (1982). Behavioral aspects of information processing for the design of management information systems. *IEEE Transactions on Systems, Man, and Cybernetics*, 12 (4), 439-450.

Blattberg, R.C. & S.J. Hoch (1990). Database models and managerial intuition: 50% model + 50% manager. *Management Science*, 36 (8), 887-899.

Cable, D. M., & T.A. Judge (2003). Managers' upward influence tactic strategies: The role of manager personality and supervisor leadership style. *Journal of Organizational Behavior,* 24 (2), 197-214.

Dawis, R.V. (1999). Toward a psychology of values. *Counseling Psychologist*, 29 (3), 458-465.

Dane, E. & M.G. Pratt (2007). Exploring intuition and its role in managerial decision making. *The Academy of Management Review,* 32 (1), 33-54.

Dunbar, E., J.L. Saiz, K. Stela & R. Saez (2000). Personality and social group value determinants of out-group bias: A cross-national comparison of Gough's PR/TO scale. *Journal of Cross-Cultural Psychology,* 31 (2), 267-275.

Finegan, J. (1994). The impact of personal values on judgments of ethical behavior in the workplace. *Journal of Business Ethics,* 13, 747-755.

Franco, L.A., & M. Meadows (2007). Exploring new directions for research in problem structuring methods: On the role of cognitive style. *The Journal of the Operational Research Society*, 58 (12), 1621-1629.

Fritzsche, D.J. (1995). Personal values: Potential keys to ethical decision making. *Journal of Business Ethics,* 14, 909-922.

Giacomino, D.E. & M.D. Akers (1998). An examination of the differences between personal values and value types of female and male accounting and nonaccounting majors. *Issues in Accounting Education,* 13 (3), 565-584.

Hasan, H. & E. Gould (2001). Support for the sense-making activity of managers. *Decision Support Systems,* 31 (1), 71-86.

Hayman, A. & T. Elliman (2000). Human elements in information system design for knowledge workers. *International Journal of Information Management,* 20, 297-309.

Hemingway, C. A. & P.W. Maclagan (2004). Managers' personal values as drivers of corporate social responsibility. *Journal of Business Ethics,* 50 (1), 33-44.

Hodkinson, G.P., J. Langan-Fox & E. Sadler-Smith (2008). Intuition: A fundamental bridging construct in the behavioural sciences. *British Journal of Psychology*, 99 (1), 1-27.

Hodkinson, G.P., E. Sadler-Smith, L.A. Burke, G. Claxton & P.R. Sparrow (2009). Intuition in organizations: Implications for strategic management. *Long Range Planning*. 42 (3), 277-297.

Huber, G. P. (1983). Cognitive styles as a basis for MIS and DSS designs: Much ado about nothing?. *Management Science*, 29 (5), 567-579.

Huijer, M. & E. Van Leeuwen (2000). Personal values and cancer treatment refusal. *Journal of Medical Ethics*, 26 (5), 358-362.

Igira, F.T. & J. Gregory (2009). Cultural Historical Activity Theory. In Dwivedi, Y.K., Lal, B., and Williams, M.D. (eds.). *Handbook of Research on Contemporary Theoretical Models in Information Systems.* Hershey, PA: IGI Global.

Illies, J.J. & R. Reiter-Palmon (2008). Responding destructively in leadership situations: The role of personal values and problem construction. *Journal of Business Ethics,* 82 (1), 251-272.

Ivan, M. & B. Ivana (2012). The Nature of Strategic Decision Making – Exploiting the role of managers' incremental and radical learning. *The Journal of International Management Studies*, 7 (2), 7-19.

Korsgaard, A.M., B.M. Meglino & S.W. Lester (1996). The effect of other-oriented values on decision-making: A test of propositions of a theory of concern for others in organizations. *Organizational Behavior and Human Decision Processes,* 68 (3), 234-245.

Little, J.D.C. (1970). Models and managers: The concept of a decision calculus. *Management Science,* 16 (8), B466-B485.

Lu, H.P., H.J. Yu & S.S.K. Lu (2001). The effect of cognitive style and model type on DSS acceptance: An empirical study. *European Journal of Operational Research,* 131 (3), 649-663.

Mason, R.O. & J.I. Mitroff (1973). A program for research on management information systems. *Management Science*, 19 (5).

Miller, C.C. & R.D. Ireland (2005). Intuition in strategic decision making: Friend or foe in the fast-paced 21st century? *The Academy of Management Executive,* 19 (1), 19-30.

Mitchell, T.R. & L.R. Beach (1990). "…Do I love thee? Let me count…" Toward an understanding of intuitive and automatic decision-making. *Organizational Behavior and Human Decision-Making,* 47, 1-20.

Oliver, B.L. (1999). Comparing corporate managers' personal values over three decades. *Journal of Business Ethics,* 20 (2), 147-161.

Pearman, R.R. & S.C. Albritton (1997). *I'm not crazy I'm just not you! The real meaning of the 16 personality types*. Palo Alto, CA: Davies-Black Publishing.

Posner, B.Z. & W.H. Schmidt (1984). Values and the American manager: An update. *California Management Review,* 26 (3), 202-216.

Posner, B.Z. & W.H. Schmidt (1992). Values and the American Manager: An update updated. *California Management Review*, 80-94.

Ravlin, E.C. & B.M. Meglino (1981). Effect of values on perception and decision-making: A study of alternative work values measures. *Journal of Applied Psychology,* 72 (4), 666-673.

Robertson, C.J. & J.J. Hoffman (2000). How different are we? An investigation of Confucian values in the United States. *Journal of Managerial Issues,* 12 (1), 34-47.

Rokeach, M. (1968). A theory of organization and change within value-attitude systems. *Journal of Social Issues,* 24 (1), 13-33.

Sadler-Smith, E. & E. Shefy (2004). The intuitive executive: Understanding and applying 'gut feel' in decision-making. *Academy of Management Executive,* 18 (4), 76-91.

Sauter, V.L. (1999). Intuitive decision-making. *Association for Computing Machinery Communications of the ACM,* 42 (6), 109-115.

Schwartz, S.H. & W. Bilsky (1987). Toward a psychological structure of human values. *Journal of Personality and Social Psychology,* 53, 550-562.

Schwartz, S.H. & L. Sagiv (1995). Identifying cultural-specifics in the context and structure of values. *Journal of Cross-Cultural Psychology,* 26 (1), 92-116.

Singhapakdi, A. & S. Vitell (1993). Personal and professional values underlying the ethical judgements of marketers. *Journal of Business Ethics,* 12, 525-533.

Sonenshein, S. (2007). The role of construction, intuition, and justification in responding to ethical issues at work: The sensemaking-intuition model. *Academy of Management Review,* 32 (4), 1022-1040.

Sprague, R. H. Jr. (1980). A framework for the development of decision support systems. *MIS Quarterly,* 4 (4), 1-26.

Tai, L.A. & R. Phelps (2000). CEO and CIO perceptions of information systems strategy: Evidence from Hong Kong. *European Journal of Information Systems,* 9 (3), 163-172.

Tihanyi, L., D.A. Griffith & C.J. Russell (2005). The effect of cultural distance on entry mode choice, international diversification, and MNE performance: A meta-analysis. *Journal of International Business Studies,* 36 (3), 270-283.

Turban, E., J.E. Aronson, T. Liang & R. Sharda (2007). *Decision support and business intelligence systems (8th edition)*. Upper Saddle River, NJ: Pearson Prentice Hall.

Van Bruggen, G.H., A. Smidts & B. Wierenga (1998). Improving decision-making by means of a marketing decision support system. *Management Science,* 44 (5), 645-657.

Van Bruggen, G.H. & B. Wierenga (2001). Matching management support systems and managerial problem-solving modes: The key to effective decision support. *European Management Journal,* 19 (3), 228-238.

Wierenga, B. (2010). Marketing and artificial intelligence: Great opportunities, reluctant partners. *Studies in Fuzziness and Soft Computing,* 258, 1-8.

Wierenga, B. & G.H. Van Bruggen (1997). The integration of marketing problem- solving modes and marketing management support systems. *Journal of Marketing,* 61 (3), 21-37.

Yukl, G. (1998). *Leadership in Organizations*. Upper Saddle River, NJ: Prentice-Hall.