Volume 15, Number 2

Printed ISSN: 1524-7252
PDF ISSN: 1532-5806

ACADEMY OF INFORMATION AND MANAGEMENT SCIENCES JOURNAL

Editors

Sharad K. Maheshwari
Hampton University

Gérard Fillion
Université de Moncton

The *Academy of Information and Management Sciences Journal* is owned and published by the DreamCatchers Group, LLC. Editorial content is under the control of the Allied Academies, Inc., a non-profit association of scholars, whose purpose is to support and encourage research and the sharing and exchange of ideas and insights throughout the world.

Authors execute a publication permission agreement and assume all liabilities. Neither the DreamCatchers Group or Allied Academies is responsible for the content of the individual manuscripts. Any omissions or errors are the sole responsibility of the authors. The Editorial Board is responsible for the selection of manuscripts for publication from among those submitted for consideration. The Publishers accept final manuscripts in digital form and make adjustments solely for the purposes of pagination and organization.

The *Academy of Information and Management Sciences Journal* is owned and published by the DreamCatchers Group, LLC, PO Box 1708, Arden, NC 28704, USA. Those interested in communicating with the *Journal,* should contact the Executive Director of the Allied Academies at info@.alliedacademies.org.

EDITORIAL BOARD MEMBERS

EDITORIAL BOARD MEMBERS

EDITORIAL BOARD MEMBERS

TABLE OF CONTENTS

LETTER FROM THE EDITORS

Welcome to the *Academy of Information and Management Sciences Journal,* the official journal of the Academy of Information and Management Sciences. The Academy is one of several academies which collectively comprise the Allied Academies. Allied Academies, Incorporated is a non-profit association of scholars whose purpose is to encourage and support the advancement and exchange of knowledge throughout the world.

The editorial mission of the *AIMSJ* is to publish empirical and theoretical manuscripts which advance the disciplines of Information Systems and Management Science. All manuscripts are double blind refereed with an acceptance rate of approximately 25%. Diversity of thought will always be welcome.

Please visit the Allied Academies website at www.alliedacademies.org for continuing information about the Academy and the *Journal*, and about all the Allied Academies and our collective conferences. Submission instructions and guidelines for publication are also provided on the website.

Sharad K. Maheshwari
Hampton University

Gérard Fillion
Université de Monckton

www.alliedacademies.org

TESTING UTAUT ON THE USE OF ERP SYSTEMS BY MIDDLE MANAGERS AND END-USERS OF MEDIUM- TO LARGE-SIZED CANADIAN ENTERPRISES

Gérard Fillion, University of Moncton
Hassen Braham, University of Moncton
Jean-Pierre Booto Ekionea, University of Moncton

ABSTRACT

Individual acceptance and use of new technologies has been studied extensively over the last two decades. And, as more and more organizations move from functional to process-based information technology (IT) infrastructure and enterprise resource planning (ERP) systems are becoming one of today's most widespread IT solutions to this movement, the research literature on ERP systems has exponentially grown. Effectively, the importance of the ERP industry to the professional information systems (IS) community is further underscored by projections indicating that it will be a $47.7 billion industry by 2011 (Jacobson et al., 2007). To study acceptance and use of ERP systems by enterprises and their employees, several models of technology adoption are used, including the Technology Acceptance Model (TAM) (Davis, 1989), its successor the TAM2 (Venkatesh & Davis, 2000), a combination of TAM2 and the model of determinants of perceived ease of use, that is TAM3 (Venkatesh & Bala, 2008), as well as the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003). But, acceptance and use of ERP systems has not been yet studied in medium- to large-sized Canadian enterprises. The aim of this study is to fill this gap. Using UTAUT model, we gathered data from middle managers and end-users in six medium to large-sized enterprises from three Canadian regions to identify influencing factors on the use of ERP systems. Data analysis was performed using structural equation modeling software, Partial Least Squares (PLS). The results highlight the key role of three independent variables (facilitating conditions, anxiety, and behavioral intention) and a moderator variable (age) of UTAUT model as influencing factors on the use of ERP systems in medium- to large-sized Canadian enterprises. The independent variable social influence can also play a less significant role ($p < 0.10$) on the use of ERP systems.

INTRODUCTION

It is now evident that information systems (IS) are used at all organizational levels to manage all activities of the enterprises, as much small- to medium-sized enterprises (SME) as

medium- to large-sized enterprises. Further, since more than a decade, enterprise-wide IS has gradually been adopted by these two types of enterprises. Indeed, it stands that one of the most pervasive organizational change activities in the last decade or so has been the implementation of enterprise-wide information technologies (IT), such as enterprise resource planning (ERP) systems, that account for 30 percent of all major change activities in organizations today (Davenport, 2000; Herold et al., 2007; Jarvenpaa & Stoddard, 1998; quoted in Morris & Venkatesh, 2010). Some estimates suggest that ERP adoption is as high as 75 percent among medium- to large-sized manufacturing enterprises (Meta Group, 2004; quoted in Morris & Venkatesh, 2010) and about 8 percent among SMEs (Raymond & Uwizeyemungu, 2007). In their comparative analysis of the factors affecting ERP system adoption between SMEs and large companies, Buonanno et al. (2005) showed that business complexity, as a composed factor, is a weak predictor of ERP adoption, whereas just company size turns out to be a very good one. In other words, according to these authors, enterprises seem not to be disregarding ERP systems as an answer to their business complexity. Unexpectedly, SMEs disregard financial constraints as the main cause for ERP system non-adoption, suggesting structural and organizational reasons as major ones. This pattern is partially different from what was observed in large organizations, argue Buonanno et al. (2005), while the first reason for not adopting an ERP system is organizational. On the other hand, Ranganathan and Brown (2006) found a positive relation between ERP system adoption and a favorable reaction on the part of investors. They also found support that ERP projects with greater functional scope (two or more modules) or greater physical scope (multiple sites) result in positive, higher shareholder returns when implementing an ERP system. And, the highest increases in returns (3.29%) are noted for ERP implementation with greater functional scope and greater physical scope.

But what is an ERP system? "An ERP system combines methodologies with software and hardware components to integrate numerous critical back-office functions across a company. Made up of a series of 'modules', or applications that are seamlessly linked together through a common database, an ERP system enables various departments or operating units such as Accounting and Finance, Human Resources, Production, and Fulfillment and Distribution to coordinate activities, share information, and collaborate." (Business Software, 2010, p. 2) The fact that all the modules are interconnected on a common database allows to avoid to a large extent, if not totally eliminate, dysfunctions and data redundancy and inconsistency which represent a major and extremely costly problem for the enterprises still using individual systems connected on a series of separate databases to coordinate the activities of their different functions or units.

And what are the key benefits of an ERP system? ERP systems are designed to enhance all aspects of key operations across a company's entire back-office – from planning through execution, management, and control. They accomplish this by taking processes and functions that were previously disparate and disjointed, and seamlessly integrating and coordinating them. As a result, an ERP system can: facilitate more efficient completion of day-to-day tasks; reduce the redundant and overlapping activities that waste time and money by standardizing core

procedures; eliminate data silos by creating a single, centralized repository of timely, accurate business data; enable more effective resource allocation and management; reduce overhead costs; and enhance strategic planning by allowing for more accurate assessment of needs, and enabling measurement of goals versus outcomes. (Business Software, 2010)

Individual acceptance and use of new technologies has been studied extensively over the last two decades. And, as more and more organizations move from functional to process-based IT infrastructure and that ERP systems are becoming one of today's most widespread IT solutions to this movement, the research literature on ERP systems has exponentially grown in recent years. Indeed, the importance of the ERP industry to the professional IS community is further underscored by projections indicating that it will be a $47.7 billion industry by 2011 (Jacobson et al., 2007). To study acceptance and use of ERP systems by enterprises and their employees, several models of technology adoption are used, including the Technology Acceptance Model (TAM) (Davis, 1989), its successor the TAM2 (Venkatesh & Davis, 2000), a combination of TAM2 and the model of determinants of perceived ease of use, that is TAM3 (Venkatesh & Bala, 2008), as well as the Unified Theory of Acceptance and Use of Technology (UTAUT) (Venkatesh et al., 2003). But, at our knowledge, acceptance and use of ERP systems has not been yet studied in medium- to large-sized Canadian enterprises. The aim of this study is then to fill this gap in investigating the following research question: What are the influencing factors on the use of ERP systems in medium- to large-sized Canadian enterprises?

The paper builds on a framework suggested by Fillion (2004) in the conduct of hypothetico-deductive scientific research in organizational sciences, and it is structured as follows: first, a literature review on the subject is presented; second, the theoretical approach which guides the study is developed; third, the methodology followed to conduct the study is described; fourth, the results of the study are reported; and the paper ends with a discussion about the findings, the theoretical and practical implications, the limitations of the study, and the future directions.

LITERATURE REVIEW

Since the beginning of the 2000s, we can see a great evolution in the research literature on ERP systems. This is translated by an important number of papers published (Botta-Genoulaz et al., 2005) in different scientific journals and reviews related to IT and business management. But, there is still a lot of work to do within this exciting and so important domain for the business management evolution, and more especially since we have to cope with the business management globalization. So we noted in the existing literature on the subject that there is no (or very few) research related to the influencing factors on the use of ERP systems in medium- to large-sized Canadian enterprises. Thus, in this study, we will try to shed some new lights about this to the body of research on ERP systems. But, first, it is important to begin by taking a look at some existing works relevant to the present study.

Some works examined the motivations to implement an ERP system. According to Davenport (1998), there are several reasons motivating a company's director to implement an ERP system in his/her enterprise. Indeed, this type of system allows to stock data on a single repository and, for this reason, to make potential gains and to decrease the additional maintenance costs of legacy systems on computers. On the other hand, there is an effect between the customers' behavior and the manufacturing production if the sales and orders systems are not linked (Davenport, 1998). In addition, if the sales and marketing service has not a mutual relation with the financial service, then managers will take decisions based either on their intuition or on out-of-date information instead of having access at all data updates from all services or units (Davenport, 1998). Botta-Genoulaz et al. (2005), Mabert et al. (2000), and Shang and Seddon (2002) outlined some major reasons why enterprises must implement and use ERP systems. A first reason, one of the technical order, is the conversion of computer systems to cope with what has come to be known as the "Year 2000" or "Y2K" software problem (for more details, see Yourdon & Yourdon, 2000), the maintenance reduction, the elimination of repetitions in data input, and the diminution of the costs associated to computer maintenance and the integration of applications allowing the use of all databases simultaneously. And a second reason, one of the strategic order, consists in helping the enterprise to grow, the improvement of ineffective "business plans", the reduction of inventory costs and the elimination of delays and errors in the preparation of customers' orders, all this in a same system and in different places. Another research has been conducted to verify the impact of ERP system implementation on operational efficiency of medium-sized enterprises (Vemuri & Palvia, 2006). These authors verified the efficiency both before and after ERP system implementation in 17 different companies of the chemical and pharmaceutical sectors. The results of the research revealed that there is no clear improvement on operational efficiency at several levels, unlike what the SAP vendor declared.

Lozinsky (1998) underlined some advantages following ERP system implementation. They are: operation costs reduction, easier access to information (allowing decision-makers to take better decisions), better negotiation with customers and providers, as well as easiness to generate non-repetitive reports. Other researchers (e.g., Holland & Light, 1999; Labruyere et al., 2002; Mabert et al., 2000) have developed questionnaires in order to identify the benefits of an ERP system. They found the following: quality of information, real-time access to information, reduction of the inventory, and improvement of the productivity, cash-flows, and previsions. However, it is to be noted that these advantages are not solely linked to the new system usage, but this one has a large contribution. Velcu (2007) conducted a study involving 14 companies from Finland who are using an ERP system. Her study clearly showed that the enterprises using the ERP system considerably improved their service time in accounting tasks and they also gained the ability to react more rapidly to changes. In the same context, Zhang et al. (2005) highlighted the success factors of an ERP implementation in China. Though an ERP implementation requires clear and precise information, these authors noted that Chinese people can tolerate inexact information and that they are also reluctant to share information with third-party people. The

study concluded that, if they want their ERP implementation be a success, Chinese enterprises must leave some cultural habits and adopt a more modern management style. This conclusion highlights the importance of the organizational culture as a key success factor of ERP system implementation. Bironneau and Martin (2002) identified the potential problems encountered throughout an ERP system implementation process. Their study showed that the main obstacles to an ERP system implementation are the capture, sharing, and codification of information, but also the system update.

Some studies revealed that, not only manufacturing enterprises can use ERP systems, but also other organizations such as banks. It is the case for the study performed by Fuss et al. (2007). Effectively, this study highlighted a set of advantages and limits of using ERP systems in the banks. In this study, 1000 banks present in 44 countries of the world were surveyed. Regarding the advantages, the authors noted a better use of databases, an improvement in security and availability of information, and a better adaptation to the different norms at which the banks must conform. As for the limits, the authors observed high system implementation costs as well as high consulting costs for the maintenance, which is generally the more expensive part for the enterprises. Furthermore, there is a lost of flexibility given the system implementation requires much efforts and the formation of employees on its usage. Thus, the replacement is difficult to perform after the implementation. There is also some dependency towards the vendors of these ERP systems (for example, SAP, Oracle, and Microsoft), not only during the implementation process but also when the time comes for the maintenance, which is considerably limiting the liberty of the enterprises.

Other studies, such as those performed by Seddon (2005), examined the relation between the ERP system and the competitive advantage. According to the findings of this study, such a system brings a great operational efficiency. Nevertheless, the study had not revealed that an ERP system can be a source of competitive advantage. A study conducted by Dai (2008) concluded to the great implication of ERP systems on the value chain, the performance, and the level of competitive advantage of the enterprises. Caruso (2003) argues that an IS such as the ERP system is becoming extremely important today. This author studied the Wyeth enterprise which is a large pharmaceutical company employing 44,000 people throughout the world and making $6.6 billion of expenses per year. Caruso's study concluded that an ERP system might be a competitive advantage if it is well integrated into the enterprise.

After numerous years of ERP systems implementation in enterprises several successes were noted but several difficulties were also encountered, leading sometimes to failures. In fact, the failure rate of ERP systems implementation is still relatively high. Davenport (1998) points out that the two main reasons why and ERP system implementation fails are: (1) the technical complexity of the solution requires a very large expertise; and (2) there is a conflict between the technical specifications of the system and the company's needs. From another point of view, Buckhout et al. (1999) argue that the difficulties encountered in an ERP system implementation are due to the following reasons: the enterprise did not make strategic choices to configure the

system and the implementation procedures; and it is always difficult to change the employees' work practices and management style. Finally, as Markus and Benjamin (1997) pointed out, the success of any IT in an enterprise depends first on users' acceptation of this technology. An ERP system implementation requires an organizational intervention which is completely changing the ways of doing and the employees' habits, argue Markus and Benjamin (1997). So the arguments evocated above clearly show how much ERP system adoption is by far more complex than any other IT (for example, e-mail, videoconferencing, and Internet). To this effect, Holsapple et al. (2005) provide the enterprises and their employees with some guidelines to follow in order to improve the chances that ERP system adoption be a success.

Finally, since UTAUT model is used as theoretical foundation in this study, we have inventoried a set of relevant studies conducted all around the world, which are testing UTAUT model and extensions. These studies are presented in Table 1. We compare the findings of our study with those of the studies described in Table 1 in the discussion and conclusions section of the paper.

Table 1: Relevant Literature on the Test of UTAUT Model and Extensions

Studies	Locations	Technologies Involved	Models/ Extensions	Variables[1]	Findings
Venkatesh et al. (2003)	USA	Online meeting, database application, portfolio analyser, proprietary accounting system	UTAUT	*Independent:* PE, EE, SI, FC *Moderator:* G, A, E, VU *Dependent:* BI, UB	The variance in BI and UB explained by UTAUT was 70%
Wang & Yang (2005)	Taiwan	Online stocking	UTAUT, personality traits	Model 1 *Independent:* EX, C, AG, N, O *Mediator:* PE, EE, SI, FC *Dependent:* BI Model 2 *Independent:* PE, EE, SI, FC *Moderator:* EX, C, A, N, O, E *Dependent:* BI	The variance in BI explained by UTAUT and personality traits was low in Model 1, and was 60% in Model 2
Anderson et al. (2006)	USA	Tablet PC	UTAUT	*Independent:* PE, EE, SI, FC, G, A, E, VU *Dependent:* UB	The variance in UB explained by UTAUT was 44.6%

Table 1: Relevant Literature on the Test of UTAUT Model and Extensions					
Studies	Locations	Technologies Involved	Models/ Extensions	Variables[1]	Findings
Pu Li & Kishore (2006)	Hong Kong	Online community Weblog systems	UTAUT, demographic characteristics	*Independent:* PE, EE, SI, FC *Demographic* G, GK, SK, E, UF	The scales for the four constructs in UTAUT had invariant true scores across most but not all subgroups
Sabherwal et al. (2006)	Everywhere in the world; meta-analysis of 121 studies between 1980 and 2004	Several different technologies	Prior models of IS success (ISD, TRA, TAM, TPB, IDT, SCT), partial UTAUT	*Independent:* S, FC, E, T, AT, P *Dependent:* SQ, PU, US, UB	The results support three of the four hypothesized relations among user-related constructs, the hypothesis about the relation between the two aspects of the context, and all five hypotheses about the effects of the context on user-related constructs
Al-Gahtani et al. (2007)	Saudi Arabia	Desktop computer applications	UTAUT	*Independent:* PE, EE, SN, FC *Moderator:* G, A, E *Dependent:* BI, UB	The variance in BI and UB explained by UTAUT was 81.2%
Chang et al. (2007)	Taiwan	Clinical DSS	UTAUT	*Independent:* PE, EE, SI, FC *Dependent:* BI, UB	The variance in BI and UB explained by UTAUT was 71%
Park et al. (2007)	China	Mobile technologies	UTAUT	*Independent:* PE, EE, SI, FC *Moderator:* G, E, ED *Dependent:* BI, UB	Gender and education were significant moderating factors, while experience was not significant
Schaper & Pervan (2007)	Australia	Information & communi-cation technologies (ICT)	UTAUT, generic framework for technology acceptance (Chau & Hu, 2002)	*Independent:* PE, EE, SI, FC, CO, AN, SE, AT *Moderator:* A, G, E, VU… *Dependent:* BI, UB	Several hypotheses were supported, but the amount of variance in BI and UB explained by the model was not mentioned
Seymour et al. (2007)	South Africa	ERP system	UTAUT	*Independent* PE, EE, SI, FC, SB, PC *Moderator*: G, A, E *Dependent*: BI	PE and EE had an influence on BI, and A moderated the relation between EE and BI
van Biljon & Kotzé (2007)	South Africa	Mobile phone	TAM, Roger's (2003) diffusion model, Kwon & Chidambaram' s (2000) model, UTAUT	*Independent* PU, PEU, FC, SI, AT *Moderator:* DF, SEF, PF *Dependent:* BI, UB	DF and PF had an influence on PEU and FC, and FC had an influence on PU, PEU, and UB

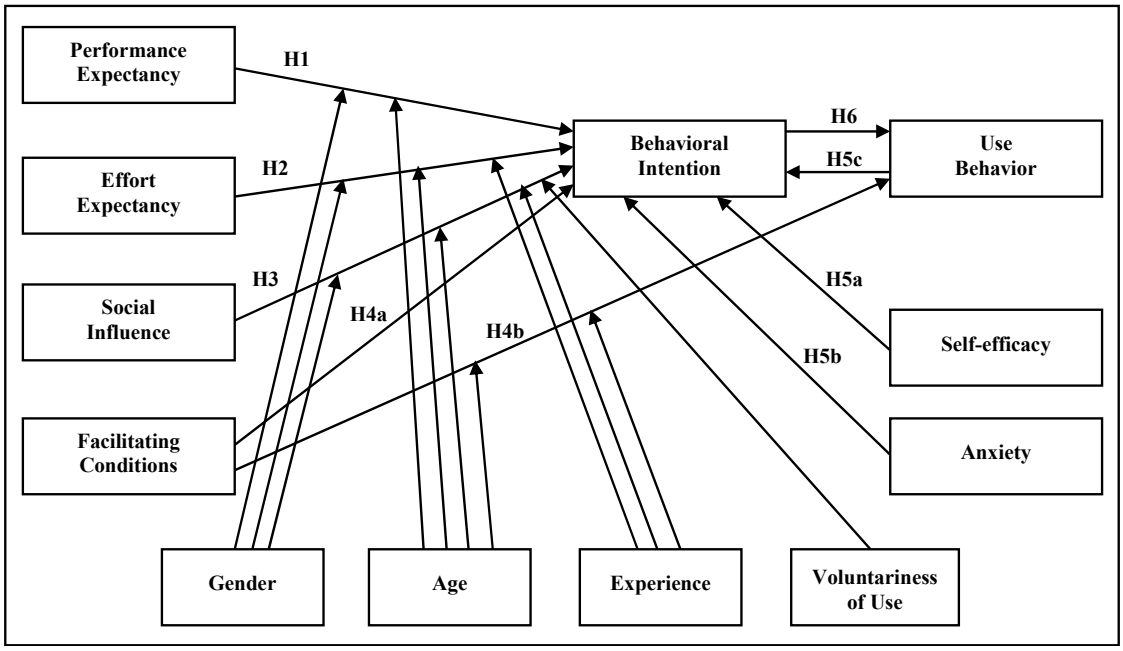
Table 1: Relevant Literature on the Test of UTAUT Model and Extensions					
Studies	Locations	Technologies Involved	Models/ Extensions	Variables[1]	Findings
Chiu & Wang (2008)	Taiwan	Web-based learning	UTAUT, expectancy-value model of achievement motivation	*Independent* PE, EE, SI, FC, SE, A, SIS, DR, RAL, AV, UV, IV *Dependent:* BI	The variance in BI explained by UTAUT and expectancy-value model of achievement motivation was 60%
Gupta et al. (2008)	India	ICT	UTAUT	*Independent* PE, EE, SI, FC *Moderator:* G *Dependent:* BI, UB	The variance in BI and UB explained by UTAUT was 28.1%
Kijsanayotin et al. (2008)	Thailand	Health IT	UTAUT	*Independent* PE, EE, SI, FC *Moderator:* E, VU *Dependent:* BI, UB	The variance in BI and UB explained by UTAUT was 81%
van Dijk et al. (2008)	Netherlands	Government Internet services	UTAUT, socio-demographic, media and channel use, and government supply-of-services factors	*Independent* PE, EE, SI, AT, A, G, ED, SDF, MCF, GSF *Dependent:* BI, UB	The variance in BI and UB explained by UTAUT was 79.4%
Venkatesh et al. (2008)	USA	Web-based front-end for informational and transactional systems	UTAUT	*Independent:* FC, BI *Moderator:* G, A, E *Dependent:* BE, UB (duration, frequency, intensity)	UTAUT explained 65%, 60%, and 60% of the variance in duration, frequency, and intensity of UB respectively
Wills et al. (2008)	USA	Electronic medical records	UTAUT	*Independent* PE, EE, SI, FC *Dependent:* BI, UB	The variance in BI and UB explained by UTAUT was 79.8%
Lu et al. (2009)	China	Instant messaging	TPB, TAM, UTAUT	*Independent:* PU, PEU, PE, SN, PBC *Mediator:* AT *Dependent:* PU, AT, BI, UB	The model explained 28%, 62%, 61%, and 18% of the variance in PU, AT, BI, and UB respectively
Sykes et al. (2009)	Finland	Content management systems	TAM, UTAUT, social networks	*Independent* BI, FC, SNF *Dependent:* UB	SNF can significantly enhance our understanding of UB (system use)

[1]PE: performance expectancy; EE: effort expectancy; SI: social influence; FC: facilitating conditions; G: gender; A: age; E: experience; VU: voluntariness of use; BI: behavioral intention; UB: use behavior; EX: extraversion; C: conscientiousness; AG: agreeableness; N: neuroticism; O: openness; GK: general computing knowledge; SK: specific Weblog-related knowledge; UF: usage frequency; S: support for IS; T: training in IS; AT: attitude toward

IS; P: participation in the development of IS; SQ: system quality; PU: perceived usefulness; US: user satisfaction; SN: subjective norm; ED: education; CO: compatibility; AN: anxiety; SE: self-efficacy; PEU: perceived ease of use; DF: demographic factors; SEF: socio-economic factors; PF: personal factors; SIS: social isolation; DR: delay in responses; RAL: risk of arbitrary learning; AV: attainment value; UV: utility value; IV: intrinsic value; SDF: socio-demographic factors; MCF: media and channel use factors; GSF: government supply-of-services factors; BE: behavioral expectation; PE: perceived enjoyment; PBC: perceived behavioral control; SNF: social network factors; SB: shared belief; PC: project communication.

THEORETICAL APPROACH

Figure 1: Theoretical Research Model



UTAUT, adapted from Venkatesh et al., 2003, p. 447)

Now that we have examined the essence of an ERP system, the results of numerous existing works discussing about the advantages, the limits, and the impacts of ERP systems on the enterprises and their employees, as well as the relevant literature on the test of UTAUT model and extensions, in the next section of the paper we develop the theoretical approach which guides the present study.

First, this study is theoretically-based on the unified view of user acceptance of IT developed and empirically validated by Venkatesh et al. (2003), that is, UTAUT model. UTAUT model integrates eight theories of user acceptance of IT derived from the existing IS literature: the theory of reasoned action (TRA), the technology acceptance model (TAM), the motivational model, the theory of planned behavior (TPB), a model combining TAM and TPB, the model of

PC (personal computer) utilization, the innovation diffusion theory (IDT), as well as the social cognitive theory (SCT). Since the development of UTAUT by Venkatesh et al. (2003), several researchers tested the model in diverse situations involving different technologies (see Table 1). In the present study, we are testing UTAUT in the context of acceptance and use of ERP systems in medium- to large-sized Canadian enterprises. The model is depicted in Figure 1.

Table 2: Definitions of Variables

Variables	Definitions
Independent variables	
Performance Expectancy	The degree to which an individual believes that using the system will help him or her to attain gains in job performance (Venkatesh, 2010).
Effort Expectancy	The degree of ease associated with the use of the system (Venkatesh, 2010).
Social Influence	The degree to which an individual perceives that important others believe he or she should use the system (Venkatesh, 2010).
Facilitating Conditions	The degree to which an individual believes that an organizational and technical infrastructure exists to support the use of the system (Venkatesh, 2010).
Self-efficacy	The degree to which an individual beliefs that he or she has the ability to perform specific task/job using the system (Venkatesh, 2010).
Anxiety	The degree of an individual's apprehension, or even fear, when he or she is faced with the possibility of using the system (Venkatesh, 2010).
Dependent variables	
Behavioral Intention	The degree to which an individual has formulated conscious plans to perform or not perform some specified future behavior (Venkatesh, 2010).
Use Behavior	Individual's positive or negative feeling about performing the target behavior (e.g., using a system) (Venkatesh, 2010).
Moderator variables	
Gender	The individual's sex (male or female) (Danko & Schaninger, 1990).
Age	The individual's age (Danko & Schaninger, 1990). In this study, age is a numeral.
Experience	Knowledge, skill, or observation of a thing or an event gained through involvement or exposure to that thing or event (e.g., using a system).
Voluntariness of Use	The degree to which using an innovation is perceived as being voluntary or of free will (Moore & Benbasat, 1991).

Figure 1 shows that UTAUT model is formed of six independent variables having an influence on two dependent variables. In addition, four moderator variables might affect the direction and/or the strength of the relations between independent variables and dependent variables (Baron & Kenny, 1986). Performance expectancy, effort expectancy, social influence, facilitating conditions, self-efficacy, and anxiety are the independent variables, while behavioral intention and use behavior are the dependent variables. As for the moderator variables, they are gender, age, experience, and voluntariness of use. All these variables are defined in Table 2.

On the basis of the theoretical research model depicted in Figure 1, we have formulated nine research hypotheses.

H1: The influence of performance expectancy on behavioral intention will be moderated by gender and age.

H2: The influence of effort expectancy on behavioral intention will be moderated by gender, age, and experience.

H3: The influence of social influence on behavioral intention will be moderated by gender, age, experience, and voluntariness of use.

H4a: Facilitating conditions will not have a significant influence on behavioral intention.

H4b: The influence of facilitating conditions on usage will be moderated by age and experience.

H5a: ERP system self-efficacy will not have a significant influence on behavioral intention.

H5b: ERP system anxiety will not have a significant influence on behavioral intention.

H5c: Attitude toward using technology will not have a significant influence on behavioral intention.

H6: Behavioral intention will have a significant positive influence on usage.

In the next section of the paper, the methodology followed to conduct the study is described

METHODOLOGY

The study was designed to gather information concerning adoption and use of ERP systems by middle managers and end-users in medium- to large-sized Canadian enterprises. Indeed, the focus of this study is on middle managers and end-users. We conducted this study using the questionnaire mailed with prepaid return envelope in medium- to large-sized Canadian enterprises. In this section, we describe the instrument development and validation, the sample and data collection, as well as the data analysis process.

Instrument Development and Validation

To conduct the study, we used the survey instrument developed and validated by Venkatesh et al. (2003). This survey instrument is of the same style to those used by Holsapple et al. (2005) to study the factors influencing ERP systems users. So this instrument was translated in French (a large part of the population, if not all, in some regions of Canada is speaking French) and both the French and English versions were evaluated by peers. This review assessed face and content

validity (see Straub, 1989). As a result, minor changes were made to reword items, consistent with Moore and Benbasat's (1991) as well as DeVellis's (2003) recommendations for scale development. Subsequent to this, we distributed the survey instrument to a group of MBA students for evaluation. Once again, minor wording changes were made. Finally, we performed some adjustments to the format and appearance of the instrument, as suggested by both peers and MBA students. As the instrument was already validated by Venkatesh et al. (2003) and several other researchers who tested UTAUT in different contexts (see Table 1), and showed to be of a great reliability, then we have not performed a pilot-test with a small sample. The evaluations by both peers and MBA students were giving us some confidence that we could proceed with a large-scale data collection.

The survey instrument as such is composed of nine parts presented as following: performance expectancy, effort expectancy, attitude toward using technology, social influence, facilitating conditions, self-efficacy, anxiety, behavioral intention to use the system, and respondent characteristics (for more details about the instrument and the items forming each construct, see Venkatesh et al. 2003, p. 460). Once a middle manager or an end-user using the ERP system in his/her enterprise was chosen by the responsible-person to answer the survey, he/she had to rate each item of the survey on a seven points Likert-type scale (1: strongly disagree … 7: strongly agree). In addition, the respondent was asked to answer some demographic questions.

Sample and Data Collection

First, in this study, we chose to survey middle managers and end-users using an ERP system in medium- to large-sized Canadian enterprises. To do that, the directors of ten medium- to large-sized enterprises from the Canadian country were contacted to participate in the study involving their usage of an ERP system. In fact, the first step was to select medium- to large-sized enterprises in Canada. And the second step was to contact the directors of these enterprises by e-mail and/or by telephone in order to get their agreement to participate in our study. During this second step, the objective of the study was presented to each director and we were verifying whether his/her enterprise was managed using an ERP system. In the case where the enterprise had not an ERP system, the director was thanked and the enterprise was retired from our list (a list of medium- to large-sized Canadian enterprises taken on the Web). Some enterprises having an ERP system have not participated in the study either because the director was lacking time or because the enterprise had a strict politic about the confidentiality of its activities. Once the director was giving us his/her agreement to participate in the study, we were sincerely thanking him/her and we were asking him/her to find someone (sometimes himself/herself) who could personally take the study in hand in the enterprise. This responsible-person had to receive the questionnaires from us and to distribute them to middle managers and end-users using the ERP system in the enterprise. The number of questionnaires sent was depending on both the size of the enterprise and the number fixed by the director contacted. Prepaid return envelopes were also

provided to the responsible-person who was distributing the questionnaires to middle managers and end-users of the ERP system. Overall, six medium- to large-sized enterprise's directors from three Canadian regions (e.g., New Brunswick, Nova Scotia, and Manitoba) agreed to participate in the study.

In the whole, over one hundred questionnaires were mailed to the six enterprises having agreed to participate in the study, and that, in two versions (French and English). Table 3 shows the distribution of the questionnaires sent to and received from the six medium- to large-sized Canadian enterprises having agreed to participate in our study.

Table 3: Distribution of the Questionnaires Sent and Received

Enterprises[1]	Questionnaires Sent	Questionnaires Received	Percentages
E1	25	23	92.0
E2	36	13	36.1
E3	40	28	70.0
E4	10	2	20.0
E5	10	1	10.0
E6	5	5	100.0
Total	126	72	57.1
Total rectified[2]	**126**	**71**	**56.3**

[1]The enterprises have been identified E1thru E6 in order to keep their anonymity.
[2]One questionnaire received has been withdrawn given too much information was lacking.

More specifically, as shown in Table 3, we posted 126 questionnaires to the responsible-persons in the medium- to large-sized Canadian enterprises having agreed to participate in our study. Only two enterprises (E4 and E5) returned few completed questionnaires. We think that middle managers and end-users in these two enterprises had too much work to complete the questionnaire and then neglected answering it. But, the response rate, in general, was excellent, as shown in Table 3. In brief, we got a response rate of 57.1%. Of the 72 middle managers and end-users that have answered our questionnaire, only one questionnaire has been withdrawn given too much information was lacking. Thus, the final response rate is 56.3%. Considering that generally the response rates of such studies involving mailed questionnaires including prepaid return envelopes are varying between 10% and 25%, the response rate of 56.3% got in this study is really exceptional.

Data Analysis Process

The data analysis of the study was performed using a structural equation modeling software, that is, Partial Least Squares (PLS-Graph 3.0). Using PLS, data have no need to follow a normal distribution and it can easily deal with small samples. In addition, PLS is appropriate when the objective is a causal predictive test instead of the test of a whole theory (Barclay et al., 1995; Chin, 1998) as it is the case in this study. To ensure the stability of the model developed to

test the research hypotheses, we used the PLS bootstrap resampling procedure (the interested reader is referred to a more detailed exposition of bootstrapping (see Chin, 1998; Efron and Tibshirani, 1993)) with an iteration of 100 sub-sample extracted from the initial sample (71 middle managers and end-users from six medium- to large-sized Canadian enterprises using ERP systems). Some analyses were also performed using the Statistical Package for the Social Sciences software (SPSS 17.0). The results follow.

RESULTS

In this section of the paper, the results of the study are reported. We begin to present some characteristics of the participants. Then we validate the PLS model developed to test the research hypotheses. Finally, we describe the results got from PLS analyses to test the research hypotheses.

Participants

The participants in this study were relatively aged, with a mean of 40.4 years and a standard deviation of 8.6 years. These statistics on the age of the participants are, in fact, consistent with the growing old population phenomenon. A few more than half of the participants were female (52.1%). As for the level of education, 11.3% of the participants in the study got a high-school diploma, 36.6% got a college degree, 35.2% completed a baccalaureate, and 8.5% completed a master. None of the participants got a doctorate. These statistics on the level of education are relatively consistent with the target participants in the study, that is, middle managers and end-users. All of the respondents in our study were full-time employees (100%). Only 25.4% of the participants in the study were using the ERP system on a voluntary basis, the other 74.6% were using the ERP system on a mandatory basis (by obligation). This can mean that most users prefer not using an ERP system and that they make it only because they have no other choice: the system is implemented in the enterprise to manage the daily activities. And, finally, near from three quarter of the respondents (69%) were using an ERP system for more than three years. Each of the other categories offered in this demographic question got a very small percentage of respondents, that is, three months (2.8%), six months (4.2%), one year (9.9%), two years (5.6%), and three years (8.5%). So these statistics on the experience using an ERP system show that most users had a great experience with the system.

Validation of the PLS Model to Test Hypotheses

First, to ensure the reliability of a construct or a variable using PLS, one must verify the three following properties: individual item reliability, internal consistency, and discriminant validity (for more details, see Yoo and Alavi, 2001).

To verify individual item reliability, a confirmatory factor analysis (CFA) was performed on independent and dependent variables of the theoretical research model. A single iteration of the CFA was necessary given all loadings of the variables were superior to 0.50 and then none item was withdrawn nor transferred in another variable in which the loading would have been higher. Indeed, in the whole, items had high loadings, which suppose a high level of internal consistency of their corresponding variables. In addition, loadings of each variable were superior to cross-loadings with other variables of the model. Hence the first criterion of discriminant validity was satisfied.

And to get composite reliability indexes and average variance extracted (AVE) in order to satisfy the second criterion of discriminant validity and to verify internal consistency of the variables, we used PLS bootstrap resampling procedure with an iteration of 100 sub-sample extracted from the initial sample (71 middle managers and end-users from six medium- to large-sized Canadian enterprises using ERP systems). The results are presented in Table 4.

Table 4" Means, Standard Deviations, Composite Reliability Indexes, Correlations, and Average Variance Extracted of Variables

Variables	*M*	*SD*	*Relia-bility Indexes*	*Correlations and Average Variance Extracted*[d]											
				1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*
1. Performance Expectancy	5.20	1.89	**0.84**	**0.78**											
2. Effort Expectancy	5.55	1.18	**0.92**	0.38	**0.85**										
3. Social Influence	4.79	1.66	**0.87**	0.34	0.35	**0.79**									
4. Facilitating Conditions	4.89	1.63	**0.74**	0.45	0.58	0.49	**0.68**								
5. Self-Efficacy	5.17	1.48	**0.85**	0.19	0.35	0.24	0.40	**0.76**							
6. Anxiety	2.00	1.30	**0.92**	-0.22	-0.30	-0.22	-0.41	-0.58	**0.86**						
7. Behavioral Intention	6.27	1.50	**0.97**	0.20	0.29	0.35	0.44	0.30	-0.51	**0.96**					
8. Use Behavior	5.23	1.52	**0.93**	0.70	0.54	0.35	0.46	0.26	-0.22	0.16	**0.88**				
9. Gender[a]	NA	NA	**NA**	0.04	0.11	0.09	-0.12	-0.11	-0.32	-0.23	-0.24	**NA**			
10. Age[b]	40.39	8.62	**NA**	-0.04	-0.03	-0.22	0.27	-0.02	0.09	-0.06	0.06	0.00	**NA**		
11. Experience[c]	NA	NA	**NA**	0.12	-0.24	0.20	0.04	0.21	0.46	0.22	0.31	0.16	0.37	**NA**	
12. Voluntariness of Use[a]	NA	NA	**NA**	0.11	0.09	-0.03	-0.06	0.02	0.33	0.12	0.24	0.13	-0.09	-0.06	**NA**

[a]This variable was coded as a nominal variable. It was measured in terms of non quantified distinct categories.
[b]This variable was coded as a numeral.
[c]This variable was coded as an ordinal variable. It was measured in terms of non quantified distinct ordered categories.
[d]Boldfaced elements on the diagonal of the correlation matrix represent the square root of the average variance extracted (AVE).
For an adequate discriminant validity, the elements in each row and column should be smaller than the boldfaced element in that row or column. NA: Not applicable.

As shown in Table 4, PLS analysis indicates that all square roots of AVE (boldfaced elements on the diagonal of the correlation matrix) are higher than the correlations with other variables of the model. In other words, each variable shares more variance with its measures than

it shares with other variables of the model. Consequently, discriminant validity is verified. Finally, as supposed previously, we can see in Table 4 that PLS analysis showed high composite reliability indexes for all variables of the theoretical research model. The variables have therefore a high internal consistency, with composite reliability indexes ranging from 0.74 to 0.97.

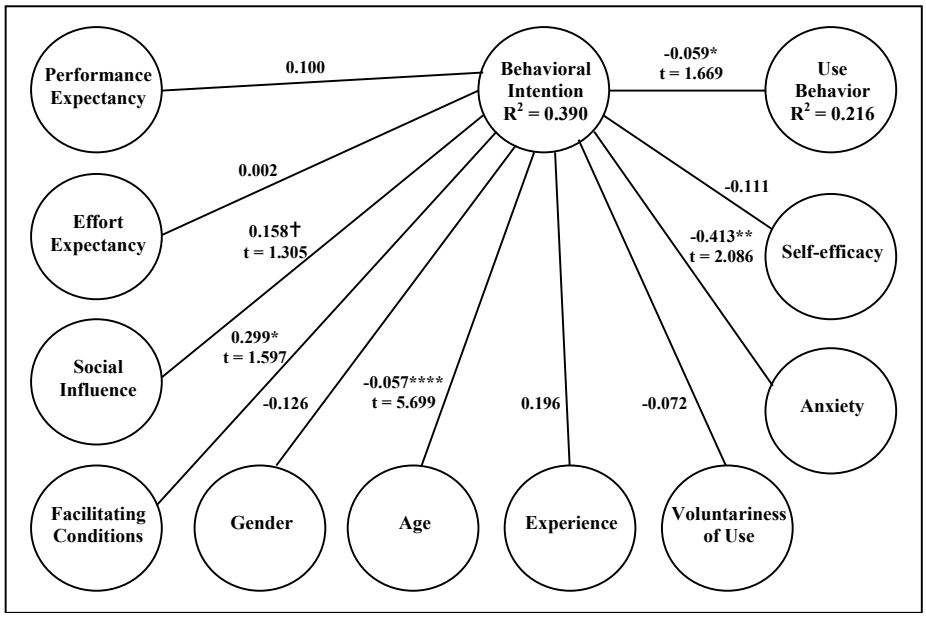
Hypothesis Testing

First, to get the significant variables in the study and the percentage of variance explained (R^2 coefficient) by all the variables of the theoretical research model, we developed a PLS model similar to those of Fillion (2005), Fillion and Le Dinh (2008), Fillion et al. (2010a), Fillion and Booto Ekionea (2010b), and Yoo and Alavi (2001). And to ensure the stability of the model, we used the PLS bootstrap resampling procedure with an iteration of 100 sub-sample extracted from the initial sample (71 middle managers and end-users from six medium- to large-sized Canadian enterprises using ERP systems). The PLS model is depicted in Figure 2.

As shown in Figure 2, all the variables of our theoretical research model, taken as independent variables, are explaining 39% of the variance on the dependant variable behavioral intention. And the dependent variable behavioral intention, taken as independent variable, is explaining 21.6% of the variance on the dependent variable use behavior. Overall, the model is explaining 60.6% of the variance on the dependent variables behavioral intention and use behavior. So the amount of variance explained by UTAUT in this Canadian study is very consistent with those explained in other studies testing UTAUT in several other countries in the world (see Table 1). In fact, in our study, UTAUT model explained more variance on the dependent variables than in the studies conducted by Wang and Yang (2005), Anderson et al. (2006), Chiu and Wang (2008), and Gupta et al. (2008); it explained about the same amount of variance on the dependent variables than in the studies performed by Venkatesh et al. (2008) and Lu et al. (2009); but the model explained a few less variance on the dependent variables than in the studies realized by Venkatesh et al. (2003), Al-Gahtani et al. (2007), Chang et al. (2007), Kijsanayotin et al. (2008), and Wills et al. (2008).

We can also see in Figure 2 that four variables were found significant influencing factors in the use of ERP systems by middle managers and end-users in medium- to large-sized Canadian enterprises. More specifically, the two more significant variables in the study are age ($t = 5.699$, $beta = -0.057$, $p < 0.001$) and anxiety ($t = 2.086$, $beta = -0.413$, $p < 0.01$). And two other variables are significant to the level of significance required in this study, that is, $p \leq 0.05$. They are facilitating conditions ($t = 1.597$, $beta = 0.299$, $p < 0.05$) and behavioral intention ($t = 1.669$, $beta = -0.059$, $p < 0.05$). On the other hand, another variable, that is social influence ($t = 1.305$, $beta = 0.158$, $p < 0.10$), is significant, but the level of significance is $p < 0.10$, while the level of significance required in this study is $p \leq 0.05$.

Figure 2: PLS Model to Get Significant Variables and Percentages of Variance Explained



†p < 0.10; *p < 0.05; **p < 0.01; ****p < 0.001.

In order that the reader can have a good overall view of the amount of variance explained by each variable in UTAUT model, we have regrouped all the variables with their corresponding amount of variance explained (R^2 coefficient) in Table 5. So Table 5 shows that the variables anxiety and behavioral intention (while taken as independent variable) are explaining alone near from 44% of the variance on the dependent variables. The variable facilitating conditions is explaining 8.3% of the variance on the dependent variable behavioral intention. Furthermore, the two variables social influence (significant at $p < 0.10$) and experience (not significant) are explaining together 7.7% of the variance on the dependent variable behavioral intention. On the other hand, it is quite surprising to see in Table 5 that, although the variable age had a very significant direct effect ($p < 0.001$) on the dependent variable behavioral intention, it is not at all contributing to explain the variance on this dependent variable.

In the last part of this section, we verify the nine research hypotheses formulated in the section related to the theoretical approach of the study. Some hypotheses are independent hypotheses (e.g., H4a, H5a, H5b, H5c, and H6), while others are moderator hypotheses (e.g., H1, H2, H3, and H4b). As for moderator hypotheses, to measure interaction effect of moderator variables: gender (G), age (A), experience (E), and voluntariness of use (VU) in order to verify hypotheses H1, H2, H3, and H4b, we used the PLS procedure proposed by Chin et al. (2003) (see the paper for more details). On the other hand, in a review of 26 papers assessing interaction effect of moderator variables published between 1991 and 2000 in IS journals, Carte and Russell (2003) found nine errors frequently committed by researchers when they estimate such an effect, and provided solutions (see their paper for more details). We tried to avoid these nine errors in

applying their solutions to test hypotheses H1, H2, H3, and H4b. Indeed, among others, in the verification of hypotheses H1, H2, H3, and H4b that follows, interaction effect of a moderator variable is significant if, and only if, the path between the latent variable (the multiplication of items of independent and moderator variables forming interaction effect) and the dependent variable is significant, as well as if the change in R^2 coefficient (the difference between the R^2 calculated before the addition of interaction effect and those calculated after the addition of interaction effect, that is, $\hat{}R^2$ (named delta R^2)) is greater than 0.

Table 5: Amounts of Variance Explained by UTAUT Variables

Variables	Beta Coefficients	t-values (one-tail)	R^2
Performance Expectancy	0.100	0.902	0.007
Effort Expectancy	0.002	0.012	0.000
Social Influence	0.158†	1.305	0.015
Facilitating Conditions	0.299*	1.597	0.083
Self-efficacy	-0.111	0.771	0.000
Anxiety	-0.413**	2.086	0.221
Behavioral Intention	-0.059*	1.669	0.216
Gender	-0.126	0.500	0.001
Age	-0.057****	5.699	0.000
Experience	0.196	1.164	0.062
Voluntariness of Use	-0.072	0.548	0.001
†p < 0.10; *p < 0.05; **p < 0.01; ****p < 0.001.			

For a matter of space, given that the test of the nine hypotheses required the development of several PLS structural equation models, we summarize PLS analyses to test each hypothesis. And, as for the PLS model developed to get the significant variables in the study and the percentages of variance explained by all of the variables of our theoretical research model (UTAUT) previously, for each PLS model developed, we used the PLS bootstrap resampling procedure with an iteration of 100 sub-sample extracted from the initial sample (71 middle managers and end-users from six medium- to large-sized Canadian enterprises using ERP systems) to ensure the stability of the model.

Concerning hypothesis 1 related to the independent variable performance expectancy (PE), the path from the latent variable PE*A*G to the dependent variable behavioral intention is not significant (t = 0.538, beta = -0.233), but there is a small change in R^2 ($\hat{}R^2 = 0.003$). Thus, contrary to our expectations, the moderator variables age (A) and gender (G) have not a significant influence on the relation between performance expectancy and behavioral intention. As a result, hypothesis 1 is not supported. The scenario is similar for hypothesis 2 related to the independent variable effort expectancy (EE). The path from the latent variable EE*A*G*E to the dependent

variable behavioral intention is not significant (t = 0.258, beta = 0.141), but there is a small change in R^2 ($\Delta R^2 = 0.001$). Thus, contrary to our expectations, the moderator variables age (A), gender (G), and experience (E) have not a significant influence on the relation between effort expectancy and behavioral intention. Hypothesis 2 is then not supported. The scenario is also similar for hypothesis 3 related to the independent variable social influence (SI), the path from the latent variable SI*G*A*E*VU to the dependent variable behavioral intention is not significant (t = 0.486, beta = 0.135), but there is a small change in R^2 ($\Delta R^2 = 0.002$). Therefore, contrary to what we expected, the moderator variables gender (G), age (A), experience (E), and voluntariness of use (VU) have not a significant influence on the relation between social influence and behavioral intention. And hypothesis 3 is not supported.

Regarding hypothesis 4a related to the independent variable facilitating conditions, the path from this variable to the dependent variable behavioral intention is very significant (t = 4.395, beta = 0.446, $p < 0.001$). Thus, contrary to what we formulated in the hypothesis, facilitating conditions have a significant influence on behavioral intention. Consequently, hypothesis 4a is not supported. As for hypothesis 4b which is also related to the independent variable facilitating conditions (FC), the path from the latent variable FC*A*E to the dependent variable use behavior (UB) is not significant (t = 0.462, beta = 0.210), but there is a small change in R^2 ($\Delta R^2 = 0.001$). So contrary to what we formulated in the hypothesis, the moderator variables age (A) and experience (E) have not a significant influence on the relation between facilitating conditions and use behavior. As a result, hypothesis 4b is not supported.

As for hypothesis 5a related to the independent variable self-efficacy, the path from this variable to the dependent variable behavioral intention is significant (t = 1.629, beta = 0.299, $p < 0.05$). So contrary to what we expected, self-efficacy has a significant influence on behavioral intention. Consequently, hypothesis 5a is not supported. The scenario is similar for hypothesis 5b related to the independent variable anxiety, the path from this variable to the dependent variable behavioral intention is very significant (t = 3.088, beta = -0.512, $p < 0.001$). Thus, contrary to our expectations, anxiety has a significant influence on behavioral intention. Hypothesis 5b is then not supported. Concerning hypothesis 5c related to the independent variable use behavior (the dependent variable use behavior was employed here as an independent variable to verify this hypothesis), the path from this variable to the dependent variable behavioral intention is not significant (t = 0.951, beta = 0.269). Thus, as we expected, use behavior has not a significant influence on behavioral intention. Hypothesis 5c is then supported. Finally, regarding hypothesis 6 related to the independent variable behavioral intention (the dependent variable behavioral intention was used here as an independent variable to verify this hypothesis), the path from this variable to the dependent variable use behavior is not significant (t = 0.870, beta = 0.269). So contrary to what we formulated in the hypothesis, behavioral intention has not a significant positive influence on use behavior. As a result, hypothesis 6 is not supported. Table 6 presents a summary of the test of hypotheses.

Table 6: Summary of the Test of Hypotheses		
Hypotheses	Results	Software (beta sig.)
H1- The influence of performance expectancy on behavioral intention will be moderated by gender and age.	Not supported	PLS (-0.233)
H2- The influence of effort expectancy on behavioral intention will be moderated by gender, age, and experience.	Not supported	PLS (0.141)
H3- The influence of social influence on behavioral intention will be moderated by gender, age, experience, and voluntariness of use.	Not supported	PLS (0.135)
H4a- Facilitating conditions will not have a significant influence on behavioral intention.	Not supported	PLS (0.446****)
H4b-The influence of facilitating conditions on usage will be moderated by age and experience.	Not supported	PLS (0.210)
H5a- ERP system self-efficacy will not have a significant influence on behavioral intention.	Not supported	PLS (0.299*)
H5b- ERP system anxiety will not have a significant influence on behavioral intention.	Not supported	PLS (-0.512****)
H5c- Attitude toward using technology will not have a significant influence on behavioral intention.	Supported	PLS (0.269)
H6- Behavioral intention will have a significant positive influence on usage.	Not supported	PLS (0.269)
*p < 0.05; ****p < 0.001.		

In summary, as shown in Table 6, only one hypothesis has been supported in our study, that is, H5c. No moderator variables had a significant influence on the relations between the independent and dependent variables involved. This is why hypotheses H1, H2, H3, and H4b were not supported. Facilitating conditions, self-efficacy, and anxiety had not a significant influence on behavioral intention. Hence hypotheses H4a, H5a, and H5b were not supported. And behavioral intention had not a significant influence on usage. Hence hypothesis H6 was not supported.

DISCUSSION AND CONCLUSIONS

The objective of this study was to identify the influencing factors in the use of ERP systems in medium- to large-sized Canadian enterprises. Only one hypothesis has been supported in the study, that is, H5c. This one suggests that attitude toward using technology has not a significant influence on behavioral intention to use technology. The fact that this hypothesis has been supported here is consistent with the results of Venkatesh et al.'s (2003) study from which we have established the theoretical foundation of our study. On the other hand, Park et al. (2007) got

opposite results in their study conducted in China. And it is the same for van Dijk et al. (2008) in their study performed in Netherlands.

So we can now answering our research question formulated in the introduction of the paper. The answer to this question will allow us to highlight the influencing factors on the use of ERP systems by middle managers and end-users in medium- to large-sized Canadian enterprises. Following some PLS data analyses (see Figure 2 and Table 5), it emerges that the significant variables are the following.

Facilitating conditions is the first significant variable with a t-value of 1.597 ($p < 0.05$) showing a positive effect on behavioral intention to use technology, which is in opposition with the results of Venkatesh et al.'s (2003) study made in USA. Indeed, these authors found that facilitating conditions have no significant influence on behavioral intention to use technology, but rather they have a significant effect on using technology and a still more pronounced effect on using technology by more aged employees having a greater experience. Testing UTAUT with an extension on individual personality traits in Taiwan, Wang and Yang (2005) found that the effects of extraversion and openness on intention to adopt a technology are significant only through the intervention of facilitating conditions. In their study conducted in USA, Pu Li and Kishore (2006) noted that facilitating conditions have no effect on gender of technology users, but they have an effect on their experience using technology. Contrary to our study and those of Venkatesh et al. (2003), Anderson et al. (2006) noted, in their study made in USA, that facilitating conditions have no positive effect on using technology. It is the same for the study realized by Chang et al. (2007) in Taiwan. A meta-analysis of 121 studies (from all around the world) published between 1980 and 2004 performed by Sabherwal et al. (2006) indicates that facilitating conditions are significant to predict behavioral intention to use technology. This meta-analysis provides strong support to the results got in our study regarding facilitating conditions. The study conducted by Schaper and Pervan (2007) in Australia is also supportive of these results. However, these results are in contradiction with those obtained by Chiu and Wang (2008) in their study realized in Taiwan. On the other hand, the results of Schaper and Pervan's (2007) study indicate a non significant influence of facilitating conditions on using technology, which is consistent with the results of the study performed by Al-Gahtani et al. (2007) in Saudi Arabia, but which is in opposition with the results of our study, those made by Venkatesh et al. (2003), those realized by Park et al. (2007) in China, those conducted by van Biljon and Kotzé (2007) in South Africa, those performed by Wills et al. (2008) and Sykes et al. (2009) in USA, those made by Gupta et al. (2008) in India, and those conducted by Kijsanayotin et al. (2008) in Thailand. Al-Gahtani et al. (2007) also found that age has a negative moderating effect of the influence of facilitating conditions on using technology, while experience has not. In another study realized by Venkatesh et al. (2008) in USA, behavioral expectation showed to have a high mediating effect of the influence of facilitating conditions on using technology. In this same study, the effect of facilitating conditions on behavioral expectation was moderated by gender, age, and experience, which is partially in contradiction with the results of our study.

The second significant variable in the present study is anxiety with a t-value of 2.086 ($p < 0.05$) associated to a negative effect (beta = -0.413). This variable is no significant in UTAUT model tested by Venkatesh et al. (2003). However, as in our study, anxiety is significant in the study performed by Schaper and Pervan (2007). In addition, anxiety is negatively linked to behavioral intention to use technology in the study conducted by Chiu and Wang (2008), which provides strong support to the results of our study.

The third significant variable found in our study is behavioral intention to use technology with a t-value of 1.669 ($p < 0.05$) associated to a negative effect (beta = -0.059). This variable is also significant in Venkatesh et al.'s (2003) study given it has a direct effect on the dependent variable use behavior (e.g., using the system or technology). The significant negative effect of this variable got in our study comparatively to the significant positive effect got in Venkatesh et al.'s (2003) study can be partially explained by the fact that we have a relatively small sample in our study, that is 71 respondents, while the sample in Venkatesh et al.'s (2003) study is 215 respondents, that is, three times greater. This significant negative effect of behavioral intention on use behavior that we got in this study can also be largely explained by the fact that 53 out of 71 respondents (75%) said using the ERP system on a mandatory basis (by obligation) and not on a voluntary basis (for more details about the statistics, see the participants sub-section at the beginning of this section). Indeed, according to us, this assuredly had the impact to negatively affect their responses to the two series of items related to the variables behavioral intention and use behavior.

The meta-analysis of 121 studies published between 1980 and 2004 made by Sabherwal et al. (2006) is also consistent with our results related to the significance of the variable behavioral intention to use technology (here the variable user attitude to use technology is employed) on the variable use behavior. And it is the same for the studies of Chang et al. (2007), van Biljon and Kotzé (2007), Wills et al. (2008), Kijsanayotin et al. (2008), van Dijk et al. 2008), Lu et al. (2009), and Sykes et al. (2009). Besides, the results of the study made by Schaper and Pervan (2007) are in opposition. In fact, these authors noted no significant effect of behavioral intention on use behavior. The study made by Gupta et al. (2008) also provides support for these opposite results. On the other hand, the results of the study conducted by Venkatesh et al. (2008) indicate that the effect of behavioral intention on use is moderated by experience such that, when using experience increases, the effect becomes more pronounced. These results are therefore consistent with those got in the present study. Besides, in their study performed in South Africa, Seymour et al. (2007) showed that performance expectancy and effort expectancy have an influence on behavioral intention, and that age has a moderating effect on the relation between performance expectancy and behavioral intention.

Finally, the fourth significant variable found in our study is the moderator variable age with a t-value of 5.699 ($p < 0.001$) associated to a negative effect (beta = -0.057). This finding is also very consistent with Venkatesh et al.'s (2003) study. In fact, age is a factor having a great influence on different variables in the studies that we examined. It is to note that some variables

have an effect on young employees, as performance expectancy, and others have an influence on more aged employees, as facilitating conditions. Anderson et al. (2006) found that age has a negative effect, but on use behavior instead of behavioral intention as it is the case in our study and in those of Venkatesh et al. (2003). Al-Gahtani et al. (2007) noted, in their study, that age has not a moderating effect of the influence of performance expectancy and effort expectancy on behavioral intention to use technology. These findings are consistent with those we got in our study, but they are in opposition with those observed in Venkatesh et al.'s (2003) study. The results of Al-Gahtani et al.'s (2003) study also indicate, on the one hand, that age has a negative moderating effect of the influence of social influence on behavioral intention, which is in opposition with the results observed in this study and in the study of Venkatesh et al. (2003) and, on the other hand, that age has a negative moderating effect of the influence of facilitating conditions on use behavior, which is in opposition with the results observed in the study of Venkatesh et al. (2003). Venkatesh et al. (2008), them, noted that the effect of facilitating conditions on behavioral expectation is moderated by age, which is partially in opposition with the results of our study. Finally, the results of the study conducted by van Dijk et al. (2008) indicate that age has no significant effect on behavioral intention to use technology, which is partially supportive of the results got in our study.

Of course, a fifth variable, that is social influence, was found significant in our study, but only to a level of significance $p < 0.10$. As mentioned earlier, this is not enough significant to be officially considered here given the level of significance required in this study is $p \leq 0.05$.
Besides, while studying the impacts of ERP systems on businesses management, we can see that the majority of employees anticipate an improvement in performance using these systems and they praise their easiness of use given the formation and help provided by trainers and/or colleagues when facing difficulties. Also, as the level of anxiety was very low and the level of self-efficacy was high in this study, then the effect will be assuredly very positive when using ERP systems in these enterprises.

In the global PLS model presented in the previous section (see Figure 2) we can see that 39% of the variance explained is on the dependent variable behavioral intention, while 21.6% of the variance explained is on the dependent variable use behavior. So the addition of moderator variables (gender, age, experience, and voluntariness of use) to the model allowed to explain 6.4% more variance (R^2 = 60.6% versus R^2 = 54.2%). This improvement in percentage of variance explained is excellent and shows that several variables can have an indirect effect (moderator) on behavioral intention to use ERP systems.

According to the demographic data got in this study, we can see that the use of ERP systems by middle managers and end-users in medium- to large-sized Canadian enterprises is not on a voluntary basis. Effectively, 74.6% of the middle managers and end-users who answered our survey said that they were using ERP systems on a mandatory basis (by obligation) instead of on a voluntary basis. On the other hand, we can see that the respondents are in majority female (52.1%). As for the level of education, most of the respondents got a college degree (36.6%), a

baccalaureate degree (35.2%), or a high-school diploma (11.3%). And all the respondents are full-time workers (100%).

Regarding the limitations of this study, according to us, the main limitation is the small sample of enterprises participating in the study, that is, six medium- to large-sized Canadian enterprises. The results would be assuredly more representative (e.g., a higher level of generalization of the results) whether more Canadian enterprises had been participating. So an increase in the number of participating Canadian enterprises could be eventually considered in future studies, which will also allow, at the same time, to identify some other factors having the potential to improve the performance of enterprises using ERP systems. This will also assuredly have an influence on research hypotheses (supported versus not supported, etc.).

As for the theoretical and practical implications of the study, they are the following. Concerning the theoretical implications, our contribution is to add a Canadian study to the body of research from all around the world on the impacts of ERP systems on medium- to large-sized enterprises and their employees. At our knowledge, no Canadian study had been performed until now in this domain. Our study therefore comes sometimes to enrich and sometimes to contradict actual theories, and thus shed new lights on the impacts of ERP systems on medium- to large-sized enterprises at the global level. Regarding the practical implications, the present study will be assuredly contributing in a significant way to the success of medium- to large-sized Canadian enterprises given it will be providing them with a good overall view of the impacts of this particular type of IS on the enterprises, their employees, and the work of these employees.

Concerning future studies, we will be conducted very soon a similar study in small- to medium Atlantic enterprises (SMEs). This will allow us to compare the results got from Atlantic SMEs with those we observed in medium- to large-sized Canadian enterprises and thus to draw some conclusions regarding their use of ERP systems. In addition, much more research is needed on the use of this particular type of IS in order to better understand its impacts on enterprises, their employees, and the work of these employees.

Finally, to conclude, the biggest surprise in this study is that most of the users of ERP systems are using the systems on a mandatory basis (by obligation) and not on a voluntary basis. This can mean that most users prefer not to use an ERP system and that they make this only because they have no other choice: the system is implemented in the enterprise to manage the activities. This finding is extremely important here given it is directly linked to the studies on the factors influencing adoption and use of ERP systems in enterprises. So, according to the results of this study, as researchers, we have now to try answering the following question: What are the specific factors in an ERP system implementation that will make such the users of this system will be using it on a voluntary basis and not on a mandatory basis? Here is a crucial question to examine in future studies to advance theories on adoption and use of ERP systems in enterprises!

ACKNOWLEDGMENTS

The authors would sincerely like to thank professor Wynne W. Chin (University of Houston at Texas) who kindly offered to us a license of the last version of his structural equation modeling software PLS to perform the data analysis of this study. We are also grateful to the *Faculté des Études Supérieures et de la Recherche* (FESR) at the University of Moncton for its financial contribution to this study.

REFERENCES

Al-Gahtani, S.S., G.S. Hubona & J. Wang (2007). Information technology (IT) in Saudi Arabia: Culture and the acceptance and use of IT. *Information & Management*, *44*, 681-691.

Anderson, J.E., P.H. Schwager & R.L. Kerns (2006). The drivers for acceptance of tablet PCs by faculty in a college of business. *Journal of Information Systems Education*, *17*(4), 429-440.

Barclay, D., C. Higgins, R. Thompson (1995). The partial least squares (PLS) approach to causal modeling, personal computer adoption and use as an illustration. *Technology Studies*, *2*(2), 285-309.

Baron, R.M. & D.A. Kenny (1986). The moderator-mediator distinction in social psychological research: Conceptual, strategic, and statistical considerations. *Journal of Personality and Personal Psychology*, *51*(6), 1173-1182.

Bironneau, L. & D.P. Martin (2002). Modélisation d'entreprise et pratiques de management implicitement liées aux ERP: enjeux conceptuels et études de cas. *Finance Contrôle Stratégie*, *5*(4), 29-50.

Botta-Genoulaz, V.B., P.A. Millet & B. Grabot (2005). A survey on the recent research literature on ERP systems. *Computers in Industry*, *56*, 510-522.

Buckhout, S., E. Frey & J. Nemec (1999). Making ERP succeed: Turning fear into promise. *IEEE Engineering Management Review*, *19*, 116-123.

Buonanno, G., P. Faverio, F. Pigni, A. Ravarini, D. Sciuto & M. Tagliavini (2005). Factors affecting ERP system adoption: A comparative analysis between SMEs and large companies. *Journal of Enterprise Information Management*, *18*(4), 384-426.

Business Software (2010). *Top 20 ERP Software Vendors Revealed*, 2010 Edition Report, Business-Software.com/ERPSoftware.

Carte, T.A. & C.J. Russell (2003). In pursuit of moderation: Nine common errors and their solutions. *MIS Quarterly*, *27*(3), 479-501.

Caruso, D. (2003). ERP as infrastructure?. *MIS*, *21*(1), 28.

Chang, I.-C., H.-G. Hwang, W.-F. Hung & Y.-C. Li (2007). Physician's acceptance of pharmacokinetics-based clinical decision support system. *Expert Systems with Applications*, *33*, 296-303.

Chau, P.Y.K. & P.J. Hu (2002). Examining a model of information technology acceptance by individual professionals: An exploratory study. *Journal of Management Information Systems*, *18*(4), 191-229.

Chin, W.W. (1998). The partial least squares approach to structural equation modeling. In G. A. Marcoulides (Ed.), *Modern Methods for Business Research* (pp. 295-336), Mahwah, NJ: Lawrence Erlbaum Associates.

Chin, W.W., B.L. Marcolin & P.R. Newsted (2003). A partial least squares latent variable modeling approach for measuring interaction effects: Results from a Monte Carlo simulation study and an electronic-mail emotion/adoption study. *Information Systems Research*, *14*(2), 189-217.

Chiu, C.-M. & E.T.G. Wang (2008). Understanding Web-based learning continuance intention: The role of subjective task value. *Information & Management*, *45*, 194-201.

Dai, Z. (2008). Supply chain transformation by ERP for enhancing performance: An empirical investigation. *Advances in Competitiveness Research*, January.

Danko, W.D. & C.M. Schaninger (1990). An empirical evaluation of the Gilly-Enis updated household life cycle model. *Journal of Business Research*, *21*, 39-57.

Davenport, T.H. (2000). *Mission Critical: Realizing the Promise of Enterprise Systems*, Boston, MA: Harvard Business School Press.

Davenport, T.H. (1998). Putting the enterprise into the enterprise system. *Harvard Business Review*, *76*(4), 121-131.

Davis, F.D. (1989). Perceived usefulness, perceived ease of use and user acceptance of information technology. *MIS Quarterly*, *13*(3), 319-340.

DeVellis, R. (2003). *Scale Development: Theory and Applications* (2nd ed.), Thousand Oaks, CA: Sage Publications.

Efron, B. & R.J. Tibshirani (1993). *An Introduction to the Bootstrap*, New York: Chapman and Hall.

Fillion, G. (2005). *L'intégration des TIC dans la formation universitaire : une étude des résultats éducationnels des étudiants dans les contextes de présence et de non présence en classe*, Doctoral Thesis (Ph.D.), Faculty of Administration, Laval University, Quebec.

Fillion, G. (2004). Publishing in the organizational sciences: An extended literature review on the dimensions and elements of an hypothetico-deductive scientific research, and some guidelines on "how" and "when" they should be integrated. *Academy of Information and Management Sciences Journal*, *7*(1), 81-114.

Fillion, G., M. Limayem, T. Laferrière & R. Mantha (2010a). Onsite and online students' and professors' perceptions of ICT use in higher education. In N. Karacapilidis (Ed.), *Novel Developments in Web-Based Learning Technologies: Tools for Modern Teaching* (Chapter 6), Hershey, PA: IGI Global Publishing.

Fillion, G. & J.-P. Booto Ekionea (2010b). Testing a moderator-type research model on the use of mobile phone. Forthcoming in *Academy of Information and Management Sciences Journal*, *13*.

Fillion, G. & T. Le Dinh (2008). An extended model of adoption of technology in households: A model test on people using a mobile phone. *Management Review: An International Journal*, *3*(1), 58-91.

Fuss, C., R. Gmeiner, D. Schireck & S. Strahunger (2007). ERP usage in banking: An exploratory study of the world's largest banks. *Journal of Information Systems Management*, *24*(2), 155-171.

Gupta, B., S. Dasgupta & A. Gupta (2008). Adoption of ICT in a government organization in a developing country: An empirical study. *Journal of Strategic Information Systems*, *17*, 140-154.

Herold, D.M., D.B. Fedor & S.D. Caldwell (2007). Beyong change management: A multilevel investigation of contextual and personal influences on employees' commitment to change. *Journal of Applied Psychology*, *92*(4), 942-951.

Holland, C.P. & B. Light (1999). A critical success factors model for ERP implementation. *IEEE Software*, *16*(3), 30-36.

Holsapple, C., Y.- Wang & J.- Wu (2005). Empirically testing user characteristics and fitness factors in enterprise resource planning success. *International Journal of Human-Computer Interaction*, *19*(3), 323-342.

Jacobson, S., J. Shepherd, M. D'Aquila & K. Carter (2007). The ERP market sizing report, 2006-2011. AMR Research Inc., Boston, MA, Retrieved July 8, 2010, from http://www.sap.com/solutions/business-suite/erp/pdf/AMR_ERP_Market_ Sizing_2006-2011.pdf.

Jarvenpaa, S.L. & D.B. Stoddard (1998). Business process redesign: Radical and evolutionary change. *Journal of Business Research*, *41*(1), 15-27.

Kijsanayotin, B., S. Pannarunothai & S.M. Speedie (2008). Factors influencing health information technology adoption in Thailand's community health centers: Applying the UTAUT model. *International Journal of Medical Informatics*, *78*, 404-416.

Kwon, H.S. & L. Chidambaram (2000). A test of the technology acceptance model: The case of cellular telephone adoption. *Proceedings of HICSS-33*, Hawaii, January 3-6.

Labruyere, E., P. Sebben & M. Versini (2002). *L'ERP a-t-il tenu ses promesses?*, Deloitte & Touche Report, p. 45.

Lozinsky, S. (1998). *Enterprise Wide Software Solutions: Integration Strategies and Practices*, Reading, MA: Addison-Wesley.

Lu, Y.,T. Zhou & B. Wang (2009). Exploring Chinese users' acceptance of instant messaging using the theory of planned behavior, the technology acceptance model, and the flow theory. *Computers in Human Behavior*, *25*, 29-39.

Mabert, V.A., A. Soni & M.A. Venkataramanan (2000). Enterprise resource planning survey of US manufacturing firms. *Production and Inventory Management Journal*, *41*(2), 52-58.

Markus, M.L. & R.I. Benjamin (1997). The magic bullet theory in IT-enabled transformation. *Sloan Management Review*, *38*(2), 55-68.

Meta Group (2004). Market research: The state of ERP services (Exec. Summary). Meta Group Inc., Stanford, CT.

Moore, G.C. & I. Benbasat (1991). Development of an instrument to measure the perceptions of adopting an information technology innovation. *Information Systems Research*, *2*(3), 192-222.

Morris, M.G. & V. Venkatesh (2010). Job characteristics and job satisfaction: Understanding the role of enterprise resource planning system implementation. *MIS Quarterly*, *34*(1), 143-161.

Park, J., S. Yang & X. Lehto (2007). Adoption of mobile technologies for Chinese consumers. *Journal of Electronic Commerce Research*, *8*(3), 196-206.

Pu Li, J. & R. Kishore (2006). How robust is the UTAUT instrument? A multigroup invariance analysis in the context of acceptance and use of online community Weblog system. *Proceedings of the SIGMIS-CPR '06* (pp. 183-189), Claremont, California, April 13-15.

Ranganathan, C. & C.V. Brown (2006). ERP investments and the market value of firms: Toward an understanding of influential ERP project variables. *Information Systems Research*, *17*(2), 145-161.

Raymond, L. & S. Uwizeyemungu (2007). A profile of ERP adoption in manufacturing SMEs. *Journal of Enterprise Information Management*, *20*(4), 487-502.

Rogers, E.M. (2003). *Diffusion of Innovations* (2nd ed.), New York: The Free Press.

Sabherwal, R., A. Jeyaraj & C. Chowa (2006). Information system success: Individual and organizational determinants. *Management Science*, *52*(12), 1849-1864.

Schaper, L. & G.. Pervan (2007). ICT and OTs: A model of information and communication technology acceptance and utilization by occupational Therapists. *International Journal of Medical Informatics*, *76*, 212-221.

Seddon, P.B. (2005). Are ERP systems a source of competitive advantage?. *Strategic Change*, *14*, 283-293.

Seymour, L., W. Makanya & S. Berrangé (2007). End-users' acceptance of enterprise resource planning systems: An investigation of antecedents. *Proceedings of the 6th ISOnEworld Conference*, Las Vegas, Nevada, April, 11-13.

Shang, S. & B.P. Seddon (2002). Assessing and managing the benefits of enterprise systems: The business manager's perspective. *Information Systems Journal*, *12*, 271-299.

Straub, D.W. (1989). Validating instruments in MIS research. *MIS Quarterly*, *13*(2), 147-169.

Sykes, T.A., V. Venkatesh & S. Gosain (2009). Model of acceptance with peer support: A social network perspective to understand employees' system use. *MIS Quarterly*, *33*(2), 371-393.

van Biljon, J. & P. Kotzé (2007). Modelling the factors that influence mobile phone adoption. *Proceedings of SAICSIT 2007* (pp. 152-161), October 2-3.

van Dijk, J.A.G.M., O. Peters & W. Ebbers (2008). Explaining the acceptance and use of government Internet services: A multivariate analysis of 2006 survey data in the Netherlands. *Government Information Quarterly*, *25*, 379-399.

Velcu, O. (2007). Exploring the effects of ERP system on organizational performance. *Industrial Management & Data Systems*, *107*(9), 1316-1334.

Vemuri, V.K. & S.C. Palvia (2006). Improvement in operational efficiency due to ERP systems implementation: Truth or myth?. *Information Resources Management Journal*, *19*(2), 18-36.

Venkatesh, V. (2010). *Technology Acceptance*, Summary of Technology Acceptance Models, Personal Website, Retrieved July 23, 2010, from http://www.vvenkatesh.com/IT/organizations/Theoretical_Models.asp.

Venkatesh, V. & H. Bala (2008). Technology acceptance model 3 and a research agenda on interventions. *Decision Sciences*, *39*(2), 273-315.

Venkatesh, V., S.A. Brown, L.M. Maruping & H. Bala (2008). Predicting different conceptualizations of system use: The competing roles of behavioral intention, facilitating conditions, and behavioral expectations. *MIS Quarterly*, *32*(3), 483-502.

Venkatesh, V., M.G. Morris, G.B. Davis & F.D. Davis (2003). User acceptance of information technology: Toward a unified view. *MIS Quarterly*, *27*(3), 425-478.

Venkatesh, V. & F.D. Davis (2000). A theoretical extension of the technology acceptance model: Four longitudinal field studies. *Management Science*, *46*, 186-204.

Wang, H.-I. & H.-I. Yang (2005). The role of personality traits in UTAUT model under online stocking. *Contemporary Management Research*, *1*(1), 69-82.

Wills, M.J., O.F. El-Gayar & D. Bennett (2008). Examining healthcare professionals' acceptance of electronic medical records using UTAUT. *Issues in Information Systems*, *9*(2), 396-401.

Yoo, Y. & M. Alavi (2001). Media and group cohesion: Relative influences on social presence, task participation, and group consensus. *MIS Quarterly*, *25*(3), 371-390.

Yourdon, E. & J. Yourdon (2000). *Time Bomb 2000: What the Year 2000 Computer Crisis Means to You!*, New Jersey: Prentice Hall.

Zhang, Z., M.K.O. Lee, P. Huang, L. Zhang & X. Huang (2005). A framework of ERP systems implementation success in China: An empirical study. *International Journal of Production Economics*, *98*, 56-80.

SCHEDULING OF PROJECTS UNDER PENALTY AND REWARD ARRANGEMENTS: A MIXED INTEGER PROGRAMMING MODEL AND ITS VARIANTS

Joel K. Jolayemi, Tennessee State University

ABSTRACT

In this paper, we develop a mixed integer linear programming (MILP) model for scheduling projects under penalty and reward arrangements. Two variants of the model (model variants I and II) are also developed. The main MILP model and its variants are applicable for scheduling for-profit and not-for-profit projects. The developments of each of the model variants are preceded by the descriptions of the conditions/assumptions under which they are applicable. Numerical examples given to test and compare the models show that they work very well. The results of the examples show that both the main model and its variants produce the same optimal values of project/activity durations and event times, bonus/penalty, and total project costs. The model variants are much easier to solve than the main MILP model. They have much less number of variables and constraints than the main model. The number of iterations before obtaining optimal solution to the main model is four to six times as large as the number of iterations before obtaining an optimal solution to each of its two variants. A remarkable and interesting finding is that the number of zero-one variables that are required for the applications of model variants I and II are 3 and 4 respectively, irrespective of project or model size. The number of the main MILP's zero-one variables is many times larger than these and the number increases rapidly with increase in project or model size. However, an advantage of the main model is that it is applicable under many conditions.

Keywords: computational efficiency, for-profit and not-for-profit organizations, project costs, project management, pro-rating variables, time-cost trade-off.

INTRODUCTION

The first published research in the applications of formal optimization techniques in project planning and scheduling is by Kelly & Walker (1959). Kelly & Walker (1959) developed what is now popularly known as time-cost-trade-off model (TCTM) with time constraints. Their pioneering work elicited a lot of research interests among many scholars and this has led to the developments and publications of different types of project scheduling models. The basic techniques of most of these models are rooted in mathematical programming. These models/problems are of different types and categories. Some of these include:

i. Client-contractor interaction problems (Szmerekovskey, 2005; Ulusory & Cabelli, 2000; Westney, 1992).
ii. Discount cash flows/maximization of net present value of projects (Etgar & Shtub, 1999; Ulusory & Cabelli, 2000; Vanhoucke et al., 2003).
iii. Resource-constrained project-scheduling problems (a few examples can be seen in Ballestin & Leus, 2009; Hurink et al., 2009; Ranjbar, 2008; Sabzehparvar & Seyed-Hosseini, 2008; Valls, Ballestin, & Quintamilla, 2004, 2005),
iv. Time-cost trade-off problems (Brucker et al., 199; Castro-Lacouture et al., 2009; Jolayemi & Oluleye, 1994; Jolayemi & Pennington, 2007; Ke & Liu, 2010; Kolish & Hartmann, 2006), and
v. Time-dependent cash flows (Dayanand & Padman 2001; Herroelen et al., 1997; Jolai, 2008; Vanhoucke et al., 2001, 2003).

Some important elements of project planning and scheduling, many of which are sub-problems or components of the major problems listed above, have also caught the attention of some authors. Among these important elements/sub-problems are:

- Fixed price contract arrangements (Gilbreath, 1992; Herroelen et al., 1997; Westney, 1992)
- Penalty and/or reward arrangement (Jolayemi, 2002; Jolayemi & Olorunniwo, 2003; Jolayemi & Pennington, 2007).
- Progress payments (Herroelen at al., 1997; Szmerekovskey, 2005), and
- Target contract arrangements (Gilbreath, 1992; Herroelen et al., 1997).

The importance of each of these key elements/sub-problems in the successful planning and execution of projects requires that much more attention be paid to the developments of more models/techniques for their efficient and effective planning and management.

Among these sub-problems, penalty and reward arrangement is among the most important element that can be used to achieve great success in the execution of a project. Yet, it is the only one that has attracted the least attention from scholars.

Penalty and reward clause is a provision in a contract that allows a contractor to be rewarded for completing a project before (and, sometimes on) a stipulated due date and allows him to be penalized for failure to complete the project by such stipulated date. Besides Jolayemi (2002), Jolayemi & Olorunniwo (2003), and Jolayemi & Pennington (2007), we have never come across any published research in which this clause is explicitly considered.

Jolayemi and Pennington (2007) developed three alternative models for scheduling projects under penalty and reward arrangements. The formulation of the penalty-reward component of the model is based on some special conditions/factors like the size and type of project, the pattern of in-flows of income or revenue from the project, and the effects of the

seasons or events of the year on these in-flows. Collectively, the three alternative models are the best (best here refers to best ability to produce accurate results) and most comprehensive models ever developed to address penalty-reward problems in project scheduling. The remaining two models developed by Jolayemi (2002) and Jolayemi and Olorunniwo (2003) are much less comprehensive in that none of the special conditions or factors considered in Jolayemi and Pennington (2007) is considered in their formulations. From now henceforth, we will refer to the three alternative models by Jolayemi & Pennington (2007) as J-P models.

The J-P models are developed for applications under three different special conditions and cases which are based on economic or profit considerations. Each model was developed for a single condition/case. This creates a great need for the developments of more comprehensive and efficient project scheduling models. That is, models that will not only be applicable under many conditions/cases but that will also be applicable for scheduling both profit and non-profit projects.

Besides the above shortcoming, none of the J-P models addresses a situation where a contractor is given some bonus for completing a project on the due date. Apart from agreeing to reward a contractor for completing a project before the due date, a project owner may like to reward him for completing the project on the due date. A close look at the J-P models will reveal that the structures of their penalty-reward components do not allow penalty to be charged against a contractor within an interval of time after (or immediately following) the due date. Although this does not affect the models' abilities to produce accurate results (due to assumption of zero bonus at the due date), the problem remains a significant model inadequacy.

In this paper, we will develop a mixed integer linear programming (MILP) model for scheduling projects under penalty and reward arrangements. The development of the model will be based on the modification and extension of model II in Jolayemi & Pennington (2007). It will be a general model. It will be applicable for scheduling for-profit and not-for-profit projects under more situations/cases than those in Jolayemi & Pennington (2007). We will address all the other shortcomings of J-P models in the developments of this general model.

Some variants of the model - variants that can be applied under some special conditions/cases that were not considered in Jolayemi & Pennington (2007) – will be presented. We will illustrate how the model's variants are obtained from the main model. We will also illustrate how the peculiarities of these special conditions/cases can be exploited and used for reducing the sizes of the model's variants, including the numbers of the zero-one variables. One of the inadequacies of the J-P models is that their sizes cannot be reduced. Instead, the numbers of their zero-one variables grow rapidly with increase in the size of a project.

We consider the J-P models to be the other variants of the main MILP model to be developed here. We will explain why we consider them so.

Numerical examples will be given to illustrate the model and its variants. We will also compare the new model with all its variants with respect to model size, accuracy, and computational efficiency (i.e. cpu time and/or number of iterations).

DEFINITION OF SYMBOLS AND THE DEVELOPMENT OF THE MAIN MODEL

Definition of Symbols

The following are the definitions of the model's decision variables and input parameters. The definitions are presented using the activity-on-arc format.

Decision variables

T_i: the start time for activity (i, j).
T_j: the completion time for activity (i, j).
T_n: the total project completion time (in weeks or months).
T_l: the earliest start time for the project.
x_{ij}: the duration (in weeks or months) for activity (i, j).
y_k; the variables that determine the value of the project completion time within an interval (t_k, t_{k+1}) and prorates bonus/penalty with respect to computed project completion time. y_k (k = 1, 2, ……., m) take values in the closed interval [0, 1].
w_k: the variable that determines the value of the project completion time within an interval (t_k, t_{k+1}) and prorates the penalty with respect to the computed project completion time. w_k (k= m, m+1, ….., s) also takes value in the closed interval [0, 1].
u_k: a binary variable that is 1 if the project is completed within the time interval [t_k, t_{k+1}] and 0 otherwise.

Input parameters

a_{ij}: the intercept made with the vertical axis by the linear approximation to the portion of the total cost curve that lies between the normal and the "crash" points with respect to activity (i, j). (See Figures 3 and 4 in the appendix).
G: the set of all activities (i, j) of the project.
B_k: the bonus or reward in dollars for completing the project in period t_k (k = 1, 2, 3, …..,m and t_m = d) before the expiration of the due date d. It is assumed that B_k decreases as t_k increases from the earliest project completion time E to the due date d.
d: the project due date. It is the time officially agreed upon by the project owner and his contractor for the completion of the project.
Δ: a very small fraction of time whose value depends on the unit of time used. If time is measured in days, Δ can be as small as 0.01; and if measured in weeks, it can be as small as 0.001, and so on.

δ_{Bm}: a very small number (which is very close to zero) that is substituted for the bonus value B_m ($B_m = 0$) at the time point t_m (where t_m is also the due date).

δ_{Pm}: a very small number (which is very close to zero) that is substituted for the penalty value P_m ($P_m = 0$) at the time point t_m (where t_m is also the due date).

E: the earliest time that is technically possible for the completion of the project. Thus $E < d$.

h_{ij}: the cost slope or gradient of the linear approximation to the portion of the total cost curve that lies between the normal and the "crash" points with respect to activity (i, j). (See Figures 3 and 4 in the appendix).

(i, j): an activity that starts at node i and terminates at node j of the project network, $i < j$.

L_{ij}: the normal time for activity (i, j).

l_{ij}: the "crash" time for activity (i, j).

λ: the constant constraint placed on the total project duration. It is the maximum allowable time for the completion of the project.

n: the end node of the project's network.

P_k: the penalty in dollars for completing the project in period t_k ($k = m+1, m+2, \ldots, s$ and $t_s = \lambda$) after the expiration of the due date d. It is assumed that P_k increases as t_k increases from d to λ.

$P_{m+\Delta}$: the penalty in dollars for completing the project at the time point $t_m + \Delta$ after the due date d.

The Development of the Main MILP Model

As mentioned in the introduction section, the development of the main MILP model is based on the second alternative model (J-P model II) by Jolayemi & Pennington (2007). Therefore, in developing the new model, we will first present the J-P model II and then proceed to modify/restructure and extend it to obtain the former.

The J-P model II is given as:

$$\text{Minimize } z = \sum_{i,j \in G} (a_{ij} - h_{ij} x_{ij}) - \sum_{k=1}^{m} B_k y_k + \sum_{k=m+1}^{s} P_k y_k \qquad \text{(M-1)}$$

Subject to:

$$T_i + x_{ij} - T_j \leq 0 \quad \text{for all } (i, j) \in G \qquad \text{(M-2)}$$

$$x_{ij} \leq L_{ij} \quad \text{for all } (i, j) \in G \qquad \text{(M-3)}$$

$$-x_{ij} \leq -l_{ij} \quad \text{for all } (i, j) \in G \qquad \text{(M-4)}$$

$$T_n - T_1 \leq \lambda \qquad \text{(M-5)}$$

$$\sum_{k=1}^{s-1} u_k = 1 \qquad \text{(M-6)}$$

$$T_n - \sum_{k=1}^{s} t_k y_k = 0 \qquad \text{(M-7)}$$

$$\sum_{k=1}^{s} y_k = 1 \qquad \text{(M-8)}$$

$$y_1 - u_1 \le 0 \qquad \text{(M-9)}$$

$$y_k - u_{k-1} - u_k \le 0 \qquad k = 2, 3, ..., s-1 \qquad \text{(M-10)}$$

$$y_k - u_{k-1} \le 0 \qquad k = s \qquad \text{(M-11)}$$

$T_i, T_j\ T_n, x_{ij} \ge 0$ for all $(i, j) \in G$ and for $i = 1, 2, ...n$;

$y_k \ge 0$ for k = 1, 2, ……., s and $u_k = 0$ for k = 1, 2, ……, s-1.

The Restructuring/Modification Process

As presently formulated, the payment of penalty between the time interval t_m and t_{m+1} is omitted in the penalty-reward component of J-P model II. Additionally, the model does not address the situation where some bonus is given to a contractor for completing a project on the due date. (We will discuss more on this in the next section). Due to these problems, the model cannot be applied under the special conditions/cases to be discussed later in the next section.

To address the problems above, we introduce a new variable w (where w is as defined earlier) and reformulate the objective function (M-1) above as follows:

$$\text{Minimize } z = \sum_{i,j \in G} (a_{ij} - h_{ij} x_{ij}) - \sum_{k=1}^{m} B_k y_k + \sum_{k=m}^{s} P_k w_k \qquad \text{(N-1)}$$

Constraints (M-2) to (M-6) of J-P model II remain unchanged but they will be re-labeled as constraints (N-2) to (N-6) in the new model.

Since a new variable w has been introduced in formulating the penalty-reward component, constraint (M-7) in the J-P model is reformulated as

$$T_n - \sum_{k=1}^{m} t_k y_k - \sum_{k=m}^{s} t_k w_k = 0 \qquad \text{(N-7)}$$

Also, because of the introduction of the new variable w, constraints (M-8) is re-formulated as:

$$\sum_{k=1}^{m} y_k + \sum_{k=m}^{s} w_k = 1 \qquad \text{(N-8)}$$

Due to the introduction of the new variables w_k (k = m, m+1, …….., s) constraints (M-9) to (M-11) are reformulated and an additional constrain is added to obtain:

$$y_1 - u_1 \le 0 \qquad \text{(N-9)}$$

$$y_k - u_{k-1} - u_k \le 0 \qquad k = 2, 3, ..., m \qquad \text{(N-10)}$$

$$w_k - u_{k-1} - u_k \le 0 \qquad k = m, m+1, ..., s-1 \qquad \text{(N-11)}$$

$$w_k - u_{k-1} \le 0 \qquad k = s \qquad \text{(N-12)}$$

The Model

Putting everything together, we have the main MILP model as:

$$\text{Minimize } z = \sum_{i,j \in G} (a_{ij} - h_{ij} x_{ij}) - \sum_{k=1}^{m} B_k y_k + \sum_{k=m}^{s} P_k w_k \qquad \text{(N-1)}$$

Subject to:

$$T_i + x_{ij} - T_j \le 0 \quad \text{for all } (i, j) \in G \qquad \text{(N-2)}$$

$$x_{ij} \le L_{ij} \qquad \text{for all } (i, j) \in G \qquad \text{(N-3)}$$

$$-x_{ij} \le -l_{ij} \qquad \text{for all } (i, j) \in G \qquad \text{(N-4)}$$

$$T_n - T_1 \le \lambda \qquad \text{(N-5)}$$

$$\sum_{k=1}^{s-1} u_k = 1 \qquad \text{(N-6)}$$

$$T_n - \sum_{k=1}^{m} t_k y_k - \sum_{k=m}^{s} t_k w_k = 0 \qquad \text{(N-7)}$$

$$\sum_{k=1}^{m} y_k + \sum_{k=m}^{s} w_k = 1 \qquad \text{(N-8)}$$

$$y_1 - u_1 \le 0 \qquad \text{(N-9)}$$

$$y_k - u_{k-1} - u_k \le 0 \qquad k = 2, 3, ..., m \qquad \text{(N-10)}$$

$$w_k - u_{k-1} - u_k \le 0 \qquad k = m, m+1, ..., s-1 \qquad \text{(N-11)}$$

$$w_k - u_{k-1} \le 0 \qquad k = s \qquad \text{(N-12)}$$

$T_i, T_j, T_n, x_{ij}, \ge 0$ for all $(i, j) \in G$ and for i = 1, 2, ……., n:

$y_k \ge 0$ for k = 1, 2, ..., m; $w_k \ge 0$ for k = m, m + 1, ..., s; and

$u_k = 0$ or 1 for k = 1, 2, ……., s-1.

Interpretation of the Models

The model's objective function minimizes the total cost of the project, including the penalty and bonus costs.

Constraint (N-2) in the model ensures that the difference between the earliest event time T_i and the latest event time T_j must be at least as large as the activity duration x_{ij}.

The normal time L_{ij} for the completion of an activity must be greater than or equal to the scheduled activity duration x_{ij}. Constraint (N-3) ensures this.

Constraint (N-4) expresses the fact that the scheduled duration of an activity must be greater than or equal to the "crash" time.

The time interval between the earliest time a project begins and the time it is completed must be less than or equal to a length of time λ. Constraint (N-5) ensures this.

Constraint (N-6) ensures that no two or more closed intervals are picked as the interval containing the optimal project completion time during any solution process.

Constraint (N-7) expresses T_n as a linear combination of t_k's (k = 1, 2, ……, s). The continuous nature of T_n and discrete nature of t_k makes this necessary. The constraint also makes it possible for the accurate value of project completion time to be determined within any closed interval $[t_k, t_{k+1}]$ and for the right amount of bonus or penalty associated with the completion time to be automatically computed using the prorating variables y_k (k = 1, 2, …….., m) and w_k (k = m, m+1, ….. s).

Constraint (N-8) ensures that none of the variables y_k (k = 1, 2, …….., m) and w_k (k = m, m+1, ….. s) has a value greater than 1. It also ensures that the sum of any successive pair of y_k or w_k is not greater than 1.

Constraints (N-9), (N-10), (N-11), and (N-12) ensure that not more than two of the variables y_k (k = 1, 2, …….., m) or w_k (k = m, m+1, ….. s) are greater than zero. They also ensure that if two of the variables are greater than zero, then the two variables must be next to each other in the sequence $\{y_k\}_{k=1}^{m}$ or $\{w_k\}_{k=m}^{s}$. This makes it possible for T_n to take any value in any closed interval $[t_k, t_{k+1}]$ at optimality.

VARIANTS OF THE MODEL

Different variants of this model can be obtained for easy adoptions and applications under some practical and special conditions/cases. First, we will present the derivations of some of this variants from the main MILP model and briefly discuss the special conditions and cases under which they can be applied.

Model Variant I

This is based on the assumptions that:

- Bonus decreases linearly within and across intervals from a maximum value at a time-point E to a minimum value of zero at the due date d (see Figure 1).
- Penalty increases linearly within and across intervals from a minimum value of zero at the due date d to a maximum value at a time point λ after the due date (see Figure 1).
- Bonus/penalty may decrease/increase at the same or different rates. In many cases, the rate of increase in penalty per unit time will be greater. A reason for this is due to the fact that, as works on the project continue beyond the due date, the project owner becomes impatient and his patience runs out fast as project works continue beyond the due date. This situation is reflected in the amount of penalty charged against a contractor.

The development of model variant I

The graphs in Figure 1 have been a useful tool in the derivation of this model variant. As can be seen in Figure 1, bonus is a decreasing linear function of time and is well-defined between the points (t_1, B_1) and (t_m, 0). Therefore, with the various $y_{k's}$ (k = 1, 2, ……, m) as defined earlier and the bonus component of the objective function and constraints (N-6) to (N-12) of the main MILP model as developed and interpreted in the last two sub-sections of the previous section, it is easy to see that knowing the coordinates (t_1, B_1) and (t_m, 0) of the end-points A_1 and A_2 respectively on the straight line A_1A_2, the bonus to a contractor for completing a project at any time-point between t_1 and t_m can be automatically determined.

Thus, in deriving this model from the main model, the only input parameters and decision variables needed for its bonus component are the bonus values B_1 and B_m (where B_m is zero) and their associated pro-rating variables y_1 and y_m respectively in the bonus component of the main MILP model. However, we will not substitute zero exactly for B_m in the bonus component. We will substitute a very small number δ_{Bm} that is very close to zero. This is to keep the variable y_m active. If this is not done, we will have only one term B_1y_1 in the bonus component of the objective function, since the term B_my_m will be zero. This will make the automatic prorating of bonus or penalty impossible when the project completion time takes a value between t_1 and t_m. Consequently, it will make the value of bonus to remain constant at B_1 for all computed values of project completion times between t_1 and t_m (t_1 and t_m inclusive).

Similarly, with the coordinates (t_m, 0) and (t_s, P_m) of the endpoints of the straight line A_2A_3 known, it is easy to see that the only decision variables and input parameters needed for the penalty component of the model are w_m, w_s, P_m (where $P_m = 0$), and P_s. However, like the case of

bonus value B_m, we will substitute a very small penalty δ_{Pm} that is very close to zero for P_m. This is for similar reasons to the ones explained above for the case of the bonus value B_m .

Based on Figure 1 and the above results, it is easy to see that the only input parameters and variables needed to derive some of the constraints of these model from constraints (N-6) to (N-12) of the main model are t_1, t_m, t_s, y_1, y_m, w_m, w_s and the zero-one variables u_1, u_m, and u_{s-1} respectively. (Note that constraints (N-2) to (N-5) of the main model will not change in this model variant since none of the above variables appear in these constraints. Therefore, we label them as constraints (I-2) to (I-5)).

On retaining only the terms containing the above input parameters and the variables in the bonus-penalty components of the objective function (N-1) and in the constraints (N-6) to (N-12) of the main model, while deleting all other terms, the model variant is obtained and given as:

$$\text{Minimize } w = \sum_{i,j \in G} (a_{ij} - h_{ij}x_{ij}) - B_1 y_1 - \delta_{Bm} y_m + \delta_{Pm} w_m + P_s w_s \qquad \text{(I-1)}$$

Subject to:

$$T_i + x_{ij} - T_j \le 0 \quad \text{for all } (i, j) \in G \qquad \text{(I-2)}$$

$$x_{ij} \le L_{ij} \quad \text{for al } (i, j) \qquad \text{(I-3)}$$

$$-x_{ij} \le -l_{ij} \quad \text{for all } (i, j) \in G \qquad \text{(I-4)}$$

$$T_n - T_1 \le \lambda \qquad \text{(I-5)}$$

$$u_1 + u_m + u_{s-1} = 1 \qquad \text{(I-6)}$$

$$y_1 + y_m + w_m + w_s = 1 \qquad \text{(I-7)}$$

$$T_n - t_1 y_1 - t_m y_m - t_m w_m - t_s w_s = 0 \qquad \text{(I-8)}$$

$$y_1 - u_1 \le 1 \qquad \text{(I-9)}$$

$$y_m - u_1 - u_m \le 0 \qquad \text{(I-10)}$$

$$w_m - u_m - u_{s-1} \le 0 \qquad \text{(I-11)}$$

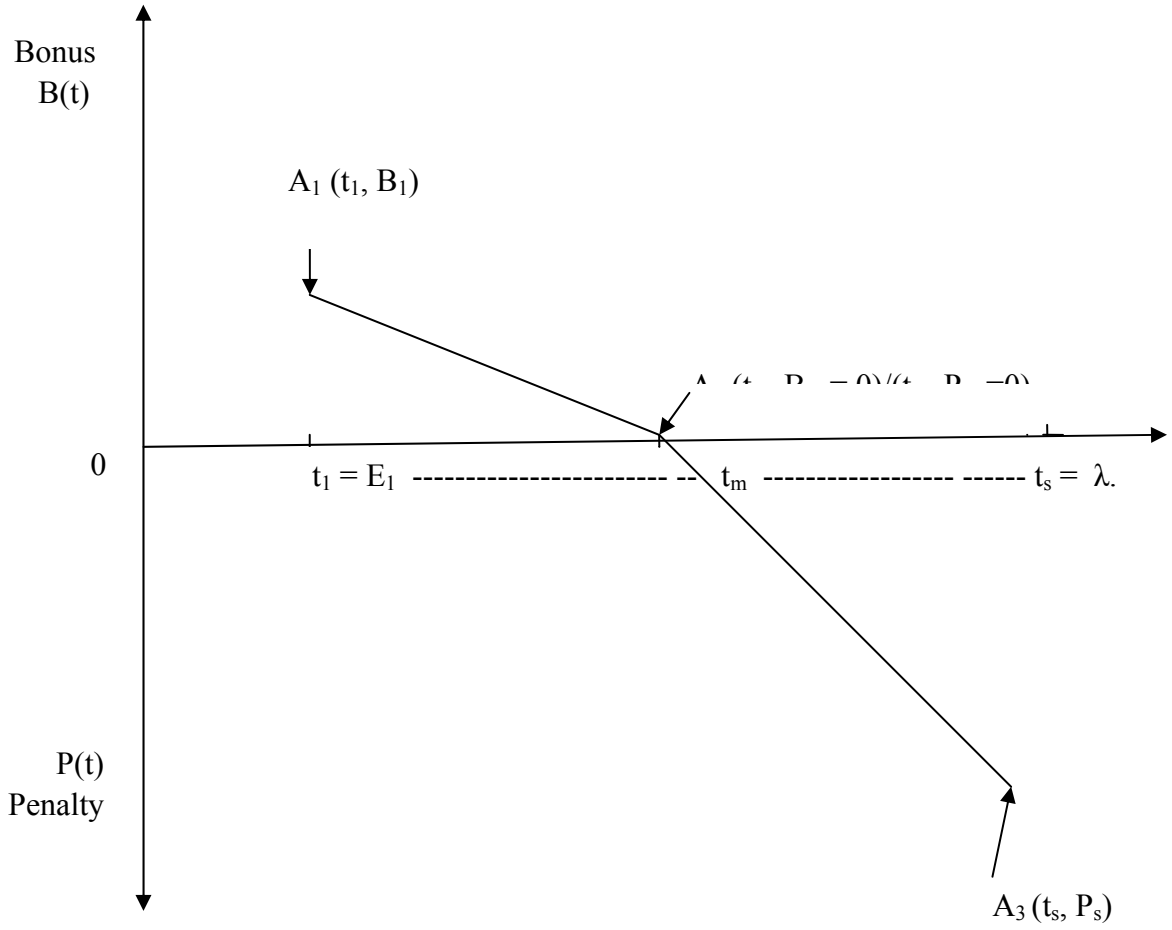
$$w_s - u_{s-1} \le 0 \qquad \text{(I-12)}$$

$$T_1, T_j, T_n, x_{ij} \ge 0 \text{ for all } (i, j) \in G \text{ and } i = 1, 2, \ldots\ldots\ldots\ldots, n$$

$$y_1, y_m, w_m \text{ and } w_s \ge 0;\ u_1, u_m, \text{and } u_{s-1} \text{ are each } 0 \text{ or } 1.$$

It should be noted that constraint (I-12) is in conformity with constraint (N-12) of the main MILP model. This can be seen from the fact that u_{s-1} is the third variable among the zero-one variables of model variant I and w_s is the fourth variable among the model's prorating variables.

Figure 1:. Bonus/penalty decreases/increases linearly with time



A very remarkable thing about this model is that it requires much less number of zero-one and pro-rating variables than the main MILP model. Equally remarkable is the fact that the numbers of zero-one and pro-rating variables required – three and four respectively – will not change, irrespective of model size. This is a great advantage over the main MILP model whose number of zero-one and pro-rating variables increase rapidly with increase in project size.

Another good advantage of this model variant is that it is very applicable in scheduling for-profit and not-for-profit projects.

In many for-profit organizations, the difficulties in predicting accurate values of revenues or profits that can be generated during any season or event of the year may discourage some organizations from tying the amount of bonus/penalty to the revenue/profits that their project can generate during any season/event of the year. A good alternative is to adopt the assumption that

bonus/penalty varies directly with time and use this model variant instead of J-P models II or III (see Jolayemi & Pennington, 2007). In any case, it is a common knowledge that there are many businesses whose revenues/profits are not seasonal.

Additionally, most government projects and the projects of many not-for-profit organizations do not have profit objectives. Therefore, the need to tie bonus/penalty to revenue/profit (seasonal or not) does not exist. The main reason for awarding bonus/penalty for early/late completion of these projects is to discourage undue delay in their executions. This model is very appropriate for scheduling such projects.

Model Variant II

The three assumptions stated for model variant I in the previous sub-section also apply to this model. In addition to this, the following two assumptions also apply:
A contractor is given some bonus for completing a project right on the due date, instead of no bonus.

The contractor is awarded some penalty for failure to complete the project on the due date. (A project owner may like to do this to show his disapproval and dislike for the continuation of works on his project beyond the due date).

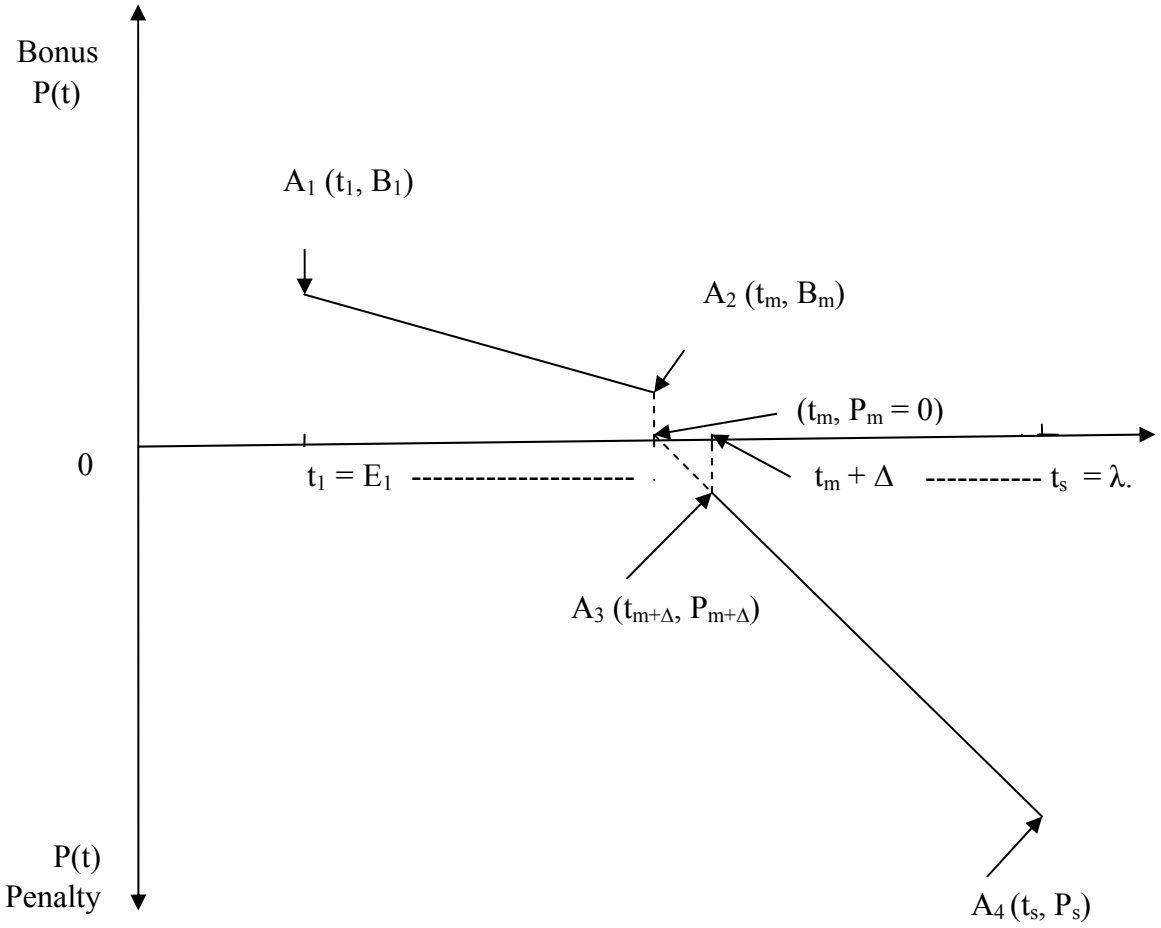
The development of model variant II

The major differences between this model and model variant I relate to the structures of their bonus-penalty components. These structural differences are the results of the differences in assumptions about the amount of bonus/penalty awarded on the due date under each model.

In the bonus-penalty component for this model variant, instead of zero bonus and zero penalty for a contractor on the due date, a contractor is awarded a non-zero bonus B_m. Also, instead of zero penalty for failure to complete the project on the due date, a contractor is awarded a non-zero penalty P_m (see Figure 2). However, it must be ascertained that penalty is not charged until the due date ends without the completion of the project. Hence, we assume that penalty $P_{m+\Delta}$ is charged at a time point $t_m + \Delta$ (see Figure 2), where Δ is as defined earlier.

Although the penalty P_m at the time-point t_m should be zero, we put its value as δ_{Pm}, instead of zero. The reason for this is to ensure that the prorating variable w_m that is associated with P_m (now δ_{Pm}) lies between the pro-rating variables y_m and $w_{m+\Delta}$ that are associated with B_m and $P_{m+\Delta}$ respectively. This will not allow a situation where B_m and $P_{m+\Delta}$ are pro-rated and added together (or subtracted from each other) in computing an optimal value for bonus or penalty.

Figure 2: Bonus decreases linearly to a none-zero minimum value and penalty Increases linearly from zero value to a maximum value



With the prorating variables for B_1, B_m, δ_{Pm}, $P_{m+\Delta}$, and P_s given as y_1, y_m, w_m, $w_{m+\Delta}$ and w_s respectively, the objective function for model variant II is:

$$\text{Minimize } z = \sum_{i,j \in G} (a_{ij} - h_{ij} x_{ij}) - B_1 y_1 - B_m y_m + \delta_{Pm} w_m + P_{m+\Delta} w_{m+\Delta} + P_s w_s \quad \ldots \text{ (II-I)}$$

It must be noted that since we have five pro-rating variables, we must have four zero-one variables associated with them. Let these be u_1, u_m, $u_{m+\Delta}$, and u_{s-1}.

Constraints (I-2) to (I-5) of model variant I also apply here. Therefore, we label them as constraints (II-2) to (II-5) of this model. After developing the rest of the constraints and putting

them together with constraints (II-2) to (II-5) and the objective function, the model variant II is obtained as follows.

$$\text{Minimize } z = \sum_{i,j \in G} (a_{ij} - h_{ij} x_{ij}) - B_1 y_1 - B_m y_m + \delta_{Pm} w_m + P_{m+\Delta} w_{m+\Delta} + P_s w_s \quad \text{(II-1)}$$

Subject to:

$$T_i + x_{ij} - T_j \leq 0 \qquad \text{for all } (i, j) \in G \qquad \text{(II-2}$$

$$x_{ij} \leq L_{ij} \qquad \text{for al } (i, j) \qquad \text{(II-3)}$$

$$- x_{ij} \leq - l_{ij} \qquad \text{for all } (i, j) \in G \qquad \text{(II-4)}$$

$$T_n - T_1 \leq \lambda \qquad \text{(II-5)}$$

$$y_1 + y_m + w_m + w_{m+\Delta} + w_s = 1 \qquad \text{(II-6)}$$

$$u_1 + u_m + u_{m+\Delta} + u_{s-1} = 1 \qquad \text{(II-7)}$$

$$T_n - t_1 y_1 - t_m y_m - t_{m+\Delta} w_{m+\Delta} - t_s w_s = 0 \qquad \text{(II-8)}$$

$$y_1 - u_1 \leq 0 \qquad \text{(II-9)}$$

$$y_m - u_1 - u_m \leq 0 \qquad \text{(II-10)}$$

$$w_m - u_m - u_{m+\Delta} \leq 0 \qquad \text{(II-11)}$$

$$w_{m+\Delta} - u_{m+\Delta} - u_{s-1} \qquad \text{(II-12)}$$

$$w_s - u_{s-1} \leq 0 \qquad \text{(II-13)}$$

$$T_1, T_j, T_n, x_{ij} \geq 0 \text{ for all } (i, j) \in G \text{ and } i = 1, 2, \ldots\ldots\ldots, n$$

$$y_1, y_m, w_m + w_{m+\Delta}, w_{s-1} \geq 0;\ u_1, u_m, u_{m+\Delta}, \text{and } u_{s-1} \text{ are each } 0 \text{ or } 1.$$

Model variant II is also applicable for scheduling for-profit and not-for-profit projects. Additionally, it has all other advantages that model variant I has.

Other Variants of the Model

The J-P three alternative models (see Jolayemi & Pennington, 2007) are all variants of the main MILP model. They are special models developed under special conditions, namely:

i. J-P model I is developed for application when penalty and bonus decreases/increases daily.
ii. J-P model II is for a situation in which bonus and penalty have piecewise linear function and bonus/penalty increases weekly, monthly, or seasonally, and
iii. J-P model III is for application when bonus and penalty follow step functions.

The three models are considered as variants of the main MILP model developed here because each of them can easily be derived from it. In other words, the MILP model needs no

extension before it can be applied to each of the three conditions stated for the applications of the three J-P models. It only needs some little modifications.

The major advantage of model variants I and II over the three J-P models is that the numbers of their zero-one and of their prorating variables are very few and do not increase with increase in the size of a project. In contrast, the numbers of the three J-P model's zero-one and prorating variables increase rapidly with increase in the size of a project.

NUMERICAL EXAMPLES AND COMPARISONS

In this section, we will give numerical examples to:

- compare each of the two model variants (model variants I and II) with the main model, and
- test how reasonable or realistic the value of the decision variables produced by the models will be.

(The three other variants of the model will not be illustrated here as they have already been well-illustrated in Jolayemi & Pennington (2007)).

Comparisons of Model Variant I with the Main Model

We gave three different numerical examples to compare model variant I with the main model. Optimal solution to each numerical example was obtained using the LINDO solver. The solver was run on a HP personal computer with a Pentium (R) 1.993 MH_3 processor under Windows XP. The results of the numerical examples are presented in Table 1.

Our objective in the first example is to test whether the main MILP model and model variant I will produce the same optimal solutions. We fed the same values of input parameters into the two models and solved the resulting numerical linear programming (LP) models.

As can be seen in the table, the results of the solution to the two numerical LP models show that the main model and model variant I produced the same optimal values of project duration and objective function. The non-zero prorating variables for each model is y_1 with an optimal value of 1.0. This shows that under this example, the optimal project duration is the same as the earliest technically possible time $t_1 = E$ for the completion of the project. Since the time E has the largest bonus associated with it, it shows that the optimal amount of bonus determined for the contractor by each model is the largest payable bonus under this example.

The purpose of the second numerical example is to check that the models will not just be picking the first partition point as the optimal project duration just because it is associated with the largest payable bonus but that they will be picking partition points on the basis of their (the

partition points') practical and technical feasibility and in such a way that the bonus to the contractor will be maximized, as much as possible, and the total project cost minimized.

To check this, we made the value of E to be smaller than its value in example 1. The value was deliberately specified in a way that makes it technically and practically impossible to complete the project at the new time-point E. The interval between the new point $t_1 =$ E and the point $t_m = d$ was then divided into 10 partition-points like in example 1. A bonus was attached to each point. The bonus attached to the new point E was the same as the bonus attached to point E in example 1. All other input parameters used for the model in example 1 were used for it in this example. The results of the solution to the model can be seen under example 2 in Table 1.

As can be seen in the table, the main model produced two non-zero prorating variables y_3 and y_4 each with value 0.5. These values were used by the model to determine the optimal project duration by prorating the two partition points t_3 and t_4. This clearly shows that, indeed, the model found the new partition point $t_1 =$ E not to be technically and practically feasible and instead of picking it, it picked two partition points t_3 and t_4 and used the optimal values of the non-zero prorating variables y_3 and y_4 to prorate them and determine the optimal project completion time. It should be noted that this prorated project completion time is the minimum time that is technically and practically feasible for the completion of the project. The values of the prorating variables were also used to prorate the value of the bonuses that were associated with t_3 and t_4 to produce an optimal bonus value for the contractor.

Thus, the results of this example shows that, in any application, the main model will not just pick a partition point or the point $t_1 =$ E to be the optimal project duration because it is associated with the largest payable bonus but, rather, it will pick partition points on the basis of their practical and technical feasibility and in such a way that the bonus to the contractor is maximized, as much as possible, and the total project cost minimized.

As can be seen in the table, the optimal project duration produced by the model in this example is the same as the optimal project duration produced by it in example 1 but the optimal total project cost is smaller than the optimal total project cost in example 1. This shows that the total cost of the project is smaller in this example than in example 1. The smaller value of the optimal total cost is due to the fact that the amount of the bonus associated with the project completion time is smaller here than in example 1.

The results under example 2 of the table (Table 1) also shows that with the new specified value of E, model variant 1 produced two prorating variables y_1 and y_{10} with optimal values 0.7222 and 0.27778 respectively instead of a single non-zero prorating variable y_1 in example 1. These optimal values of the prorating variables were used to determine the value of the optimal project duration. They were also used to prorate the zero or near-zero bonus value δ_{Bm} at the due date $t_m = d$ and the bonus value associated with the earliest project

completion time $t_1 = E$ to produce an optimal bonus value for the contractor. It is easy to see that this prorated optimal value of bonus is less than the bonus value attached to the time point E.

Therefore, the results of example 2 for model variant I shows that, like the main model and in any application, model variant I will not just pick a partition point or the point $t_1 = E$ to be the optimal project duration because it is associated with the largest payable bonus but, rather, it will pick partition points on the basis of their practical and technical feasibility and in such a way that the bonus to the contractor will be maximized, as much as possible, and the total cost minimized.

As can be seen in the table, the optimal project completion time and optimal total project cost produced by model variant I in this example are also the same with the values produced by the main model. This supports our earlier claim that the two models produce the same results.

The purpose of example 3 is to enable us study the two models further and validate some of the conclusions made earlier from the two previous examples on the model.
The size of the project involved in the example is relatively larger than the sizes of the projects in examples 1 and 2. However, instead of having more partition points for the main model between the points $t_1 = E$ and $t_m = d$, and the points $t_m + \Delta$ and t_s (see Figures 1 and 2) in this example than in the previous examples, we have fewer partition points. Thus, the interval between partition points is larger here than in the previous example. It should be noted that model variant I requires only three partition points, namely the partition points $t_1 = E$, $t_m + \Delta$, and t_s or λ (see Figure 1) and that the intervals between these partition points are larger in this example than in the previous examples. Thus, the example enables us to test how the two models perform when we have larger intervals between partition points and when project size increases.

We obtained solutions to the two models after feeding all input parameters into them. The results of the solutions are presented under example 3 in Table 1. The results show that the non-zero prorating variable produced by the main model is $y_2 = 1.0$. This shows that the main model found the first partition-point $t_1 = E$ not to be practically and technically feasible. It has therefore selected the point $t_2 = 40$, which is the next practically and technically feasible point and whose selection helped in maximizing the bonus to the contractor while at the same time minimizing the total project cost.

The results in the example also show that the non-zero prorating variables produced by model variant I are $y_1 = 0.857143$ and $y_8 = 0.142857$. This shows that, like the main model, model variant I also found the point $t_1 = E$ not to be practically and technically feasible and had to prorate the two points $t_1 = E$ and t_8 (or t_m) $= d$ using the optimal values of the two non-zero prorating variables to obtain the best value, 40 weeks, for the project completion time. Besides producing the same optimal values of project duration, the two models produced the same optimal values of total project cost.

Therefore, the results in this example have validated our conclusion in example 2 that, in any application, the main model and model variant I will not just pick the first partition points to be the optimal project completion times because the points are associated with the largest payable bonus but, rather, they will pick partition points on the basis of their (the partition points') practical and technical feasibility and in such a way that bonuses to contractors will be maximized, as much as possible, and the total project costs minimized. The results have also validated our conclusion in the previous two examples that the two models produce the same results.

Table 1: The results of the examples for the main MILP model and model variant I

Examples	Model	Number of activities	Number of constraints	Total number of variables	Number of zero-one variables	Non-zero prorating variables	Optimal Project duration	Optimal objective function value	Number of iterations
1	Main model	12	55	51	13	$y_1 = 1.0$	31	519	64
	Model variant I	12	44	30	3	$Y_1 = 1.0$	31	519	42
2	Main model	12	60	61	18	$y_3 = 0.5$ $y_4 = 0.5$	31	469	541
	Model Variant I	12	44	30	3	$y_1 = 0.722$ $y_{10} = 0.278$	31	469	84
3	Main Model	15	62	52	11	$y_2 = 1.0$	40	362	401
	Model variant I	15	53	35	3	$y_1 = 0.857$ $y_8 = 0.143$	40	362	94

As can be seen in Table 1, the results of the three numerical examples show that the numbers of the variables and constraints of model variant I are much less than those of the main model. The number of zero-one variables of model variant I in each of the examples is 3 while that of the main model is, at least, three to six times as large. Furthermore, the number of iterations before reaching an optimal solution is much larger for the main model than for model variant I. Sometimes, it is four to six times as large. All these show that the main MILP model is more difficult to solve than model variant I. However, it is very obvious from the results of the three numerical examples that both models produce very good results.

Comparisons of Model Variant II with the Main Model

Like the case of model variant I, we gave three different numerical examples to compare model variant II with the main model. The values of the input data used in each of these three examples are the same as the values of input data used in the corresponding example in the previous sub-section.

The results of the solutions to the three examples are presented in Table 2. The results presented in the 7th, 8th, and 9th columns of the table shows that the optimal values of the non-zero variables, project duration, and objective function produced by the main model in each example are the same with the values produced by the corresponding example in the previous sub-section (see Table 1). The results presented in these three columns also show that the optimal values produced by model variant II in each example are the same with the values produced by model variant I in the corresponding example in the previous sub-section (see also Table 1).

From these results, it is very clear that, like the main model and model variant I, model variant II will also be determining project completion times on the basis of their (the project duration's) practical and technical feasibility and in such a way that the bonus to the contractor is maximized, as much as possible, and the total project cost minimized. Therefore, it can be concluded that model variant II also produces very good results.

Table 2: The results of the examples for the main MILP model and model variant II

Examples	Model	Number of activities	Number of constraints	Total Number of variables	Number of Zero-one variables	Non-zero prorating variables	Optimal project duration	Optimal objective function value	Number of iterations
1	Main model	12	55	51	13	$y_1 = 1.0$	31	619	64
	Model variant II	12	45	32	4	$y_1 = 1.0$	31	619	41
2	Main model	12	60	61	18	$y_3 = 0.5$ $y_4 = 0.5$	31	569	220
	Model variant II	12	45	32	4	$y_1 = 0.722$ $y_{10} = 0.278$	31	569	172
3	Main model	15	62	52	11	$y_2 = 1.0$	40	462	301
	Model variant II	15	54	37	4	$y_1 = 0.857$ $y_8 = 0.143$	40	462	115

As can be seen from Tables 1 and 2, the numbers of variables and constraints of model variant I are less than those of model variant II by 2 and 1 respectively. The numbers of iterations before reaching optimal solutions are generally higher for model variant II than for model variant I. This shows that the one-unit difference between the number of zero-one variables of model variants I and II makes some difference in their solution process.

However, the results in Table 2 show that the numbers of variables, constraints, and iterations are much larger for the main model than for model variant II. The number of zero-one variables for model variant II in each of the examples is 4 while that of the main model is more than three or four times as large. The number of iterations before reaching optimal solutions are

very much higher for the main model than for model variant II. This shows that the main MILP model is more difficult to solve than model variant II.

We would like to remark here that it is much easier to solve the two model variants developed in this paper than to solve the other model variants in Jolayemi and Pennington (2007). None of the J-P model variants is easier to solve than the main MILP model. The main reason for this is that the numbers of their binary variables remain the same as that of the main model during any application.

We would also like to remark that the LINDO solver is very efficient at solving these models. After entering the input data for each example, the solver produced the optimal solution instantaneously at a click on the Solve command. The Optimizer Status that appeared immediately after the solution to each problem showed the elapse time for each solution to be zero. This shows that the CPU time for the solution to each model is virtually zero.

CONCLUSIONS

All the earlier stated objectives of this research have been well-achieved, namely:

- A mixed integer programming (MILP) model for scheduling projects under penalty and reward arrangements has been developed.
- Two variants of the new MILP model, model variants I and II, have also been developed for applications under some conditions/cases that were not considered in Jolayemi & Pennington (2007)
- The derivations of the two model variants from the main model have been clearly presented.
- All the shortcomings of the J-P models (see Jolayemi & Pennington, 2007) have been well addressed in developing the main model and its variants.
- The main model and its two variants have been tested and compared using some numerical examples.

In developing the main MILP model, we have restructured and extended one of the earlier models, J-P model II, developed by Jolayemi & Pennington (2007) by defining and integrating new variables, and new components and constraints into it while addressing some of its (J-P model's) shortcomings. The main model's two variants have been developed by modifying and restructuring the main MILP model. The modification and structuring of the main model to produce model variant I are based on three sets of well-defined assumptions and on Figure 1. Model variant II has been similarly developed based on a set of two assumptions and on Figure 2. Full details of the processes involved in developing the three models are clearly presented in the section devoted to model development in this paper.

In each of the numerical examples given, the main models and its two variants produce the same optimal values of project completion time and total project cost. The results of the

examples also show that the models determine optimal project completion times on the basis of the practical and technical feasibility of the completion times and in such a way that bonuses to the contractors are maximized, as much as possible, while total project costs are minimized. In other words, the examples show that the main model and each of its two variants produce very good results.

The results of the examples also show that the number of variables and constraints of the model variants I and II are much less than those of the main model, indicating that the main model is far more difficult to solve than its two variants.

The paper has made great theoretical contributions to knowledge in the area of project scheduling. These contributions include:

- *The development of the main model, which is the most general model among the few models ever developed for scheduling projects under penalty and reward arrangements:*
- Unlike the earlier models of its type, the main model can be applied under any condition.
- *The in-built structural advantages of the new model and its two variants over the J-P models* (see Jolayemi and Pennington, 2007), namely:
  - None of the J-P models allows a bonus to be paid a contractor for completing the project right on the due date. All the three new models developed here allow that.
  - The J-P models are structured in ways that make the payment of penalty between the partition-point $t_m = d$ (the due date) and the next partition-point t_{m+1} (the next partition-point after the due date) impossible. This major problem has been addressed in the three new models.
- *The small number of zero-one variables required for the applications of the new model variants:*
  The applications of the new model variants require only three and four zero-one variables respectively, no matter the size of a project. As far as we know, every one of the existing project scheduling models of their type requires much larger number of zero-one variables and this number increases rapidly with increase in project size.
- *The uniqueness and novelty of many of the constraints and components of the main model and its two variants:*
  We have developed and followed some new and innovative processes and procedures in developing many of the constraints and components of the main MILP model and its two variants. These processes and procedures are things that can be found very useful by many mathematical modelers.

Both the new main MILP model and its two variants will find very useful and widespread applications in for-profit and not-for-profit organizations.

In some for-profit organizations, the difficulties in predicting accurate values for revenues or profits during any season or event of the year may make it difficult for these organizations to apply the J-P model's I and II. A good alternative is to adopt the assumption that bonus/penalty varies directly with time and use model variants I and II developed here.

It will be very easy to find solutions to any of the models with any professional solver. The LINDO solver has been shown to be very efficient at finding solutions to the models.

REFERENCES

Ballestin, F. & R. Roel (2009). Resource-constrained project scheduling for timely project completion with stochastic activity durations. *Production and Operations Management*, 18(4), 459-474.

Brucker, P., A. Drexl, R. Mohring, K. Neumann & E. Pesch (1999). Resource-constrained project scheduling: notation, classification, models, and methods. *European Journal of Operations Research*, 112, 3 – 41.

Castro-Lascouture, D., G.A. Suer, J. Gonzalez-Joaqui & J.K. Yates (2009). Construction project scheduling with time, cost, and material restrictions using fuzzy mathematical models and critical path method. *Journal of Construction Engineering and Management*, 135(10), 1096-1104.

Dayanand, N. & R. Padman (2001). Project contracts and payment schedules: the client's problem. *Management Science*, 47, 1654 –1667.

Etgar, R. & A. Shtub (1999). Scheduling project activities to maximize the net present value the case of linear time-dependent cash flows. *International Journal of Production Research*, 37(2), 329 – 339.

Gilbreath, R.D. (1992). *Managing construction contracts (First Edition)*. New York, NY: John Wiley and Sons, Inc.

Herroelen, W. P.V. Dommelen & E.L. Demeulemeester (1997). Project network models with discounted cash flows: a guided tour through recent developments. *European Journal of Operations Research*, 100, 97- 121.

Hurink, J.L., A.L. Kok, J.J. Paulus & J.M.J. Schutten (2009). Time-constrained project scheduling with adjacent resources. *Proceedings of the Multidisciplinary International Conference on Scheduling: Theory and Applications*, 761-763.

Jolai, Fariborz (2008). A model for project scheduling with fuzzy precedence links. *Australian Journal of Basic and Applied Sciences*, 2(4) 1356-1361.

Jolayemi, J.K. (2002). A model for scheduling projects under the condintion of inflation and under penalty and reward arrangements. *Orion: The Journal of Operations Research Society of South Africa*, 17, 81.99.

Jolayemi, J.K., F.O. Olorunniwo & J.B. Pennington (2003). On the scheduling of projects under the condition of inflation and under penalty and reward arrangement. *Proceedings of the Annual General Conference of the Decision Sciences Institute.*

Jolayemi, J.K. & A.E. Oluleye (1994). Scheduling of projects under the condition of inflation: a time-cost trade-off model. *Omega: The International Journal of Management Science*, 21, 481-487.

Jolayemi, J.K. & J.B. Pennington (2007). Alternative models for scheduling projects under penalty and reward arrangements. *The International Journal of Operations and Quantitative Management*, 13(1) 47 – 61.

Ke, H. & B. Liu (2007). Fuzzy project scheduling problem and its hybrid intelligent algorithm *Applied Mathematical Modelling*, 34(2) 301-308.

Kelly, J.K. & M.R. Walker (1959). Critical path planning and scheduling. *Proceedings, Eastern Joint Computer Conference*, 160-173.

Kolisch, R. & S. Hartmann (2006). Experimental investigation of heuristics for resource-constrained project scheduling: An update. *European Journal of Operations Research*, 174(1), 23 – 37.

Ranjbar, M. (2008). Solving the resource-constrained project scheduling problem using filter-and-fan approach. *Applied Mathematics and Computation*, 2001, 313-318.

Sabzehparvar, M. & M. Seyed-Hosseini (2008). A mathematical model for the multi-mode resource-constrained project scheduling problem with mode dependent time lags. *The Journal of Supercomputing*, 44(3) 257-273.

Szmerekovsky, J.G. (2005). The impact of contractor behaviour on the client's payment-scheduling problem. *Management Science*, 51(4), 629 – 640.

Ulusory, G. & S. Cebelli (2000). An equitable approach to the payment scheduling problem in project management. European. *Journal of Operations Research*, 127, 262-278.

Valls, V., F. Ballestin & M.S. Quintanilla (2005). A Technique that pays. *European Journal of Operations Research*, 165, 375-387.

Valls, V., F. Ballestin.& M.S. Quintanilla (2004). A population-based approach to the resource-constrained project scheduling problem. *Annals of Operations Research*, 131, 305-324.

Vanhoucke, M., E. Demeulemeester & W. Herroelen (2003). Progress payments in project scheduling problems. *European Journal of Operations Research*, 143, 604-620.

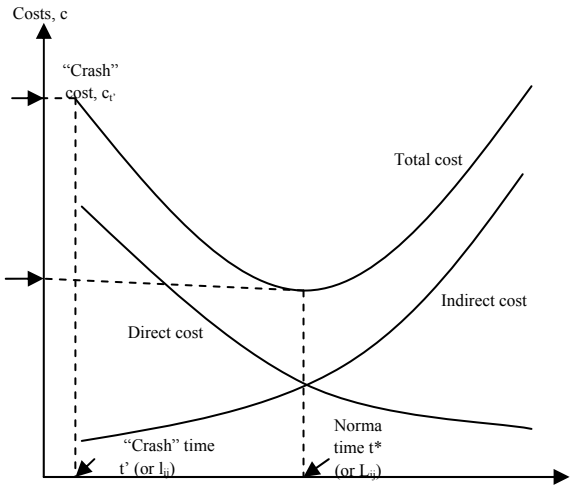
Vanhoucke, M., E. Demeulemeester & W. Herroelen (2001). Maximizing the net present value of a project with linear time-dependent cash flows. *International Journal of Production Research*, 39(14), 3159 – 3181.

Westney, R. E. (1992). *Commercial management of multiple small projects*. Monticello, NY: Marcel Dekker Inc.

APPENDIX

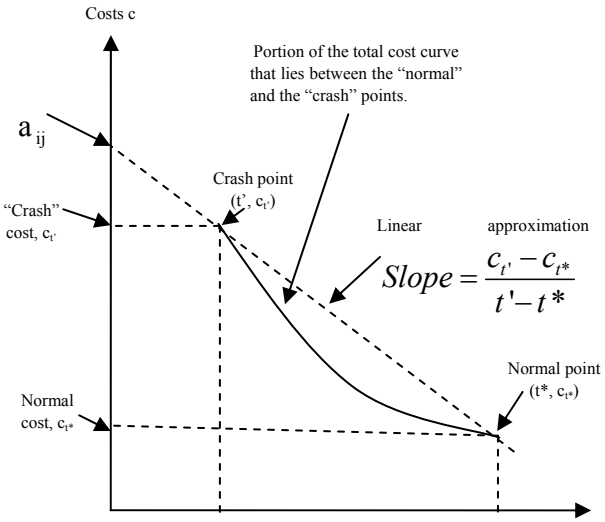
The Kelly-Walker Time-Cost Trade-off Curves (TCTC)

Figure 3: Graphs of the direct, the indirect and total costs for an activity when there is no Inflation



Normal cost, c_{t^*}

Figure 4: Linear approximation to the total-cost curve for an activity



THE HUMAN SIDE OF TECHNOLOGY PROJECT PERFORMANCE: EFFECTS OF SATISFACTION, PERCEIVED TECHNOLOGY POLICY, TASK SIGNIFICANCE AND TRAINING

Russell Teasley, North Georgia College and State University
Mark Jordan, North Georgia College and State University
Vinita Sangtani, North Georgia College and State University

ABSTRACT

Socio-technical systems theory provides a conceptual foundation for testing five behavioral relationships in a technology-based project environment. Socio-technical systems emphasize work designs that focus on the human side of technology. Data collected from technology development project teams were used to test training, satisfaction and perceived technology policy as independent influences on project effectiveness. Task significance was also tested in the model and found to positively moderate training, but its interaction was insignificant as a moderator of perceived technology policy. These findings contribute to the body of technology and innovation literature and stress the importance of considering human factors in the design and implementation of technological systems.

INTRODUCTION

The structural role of projects is well-established within product development, innovation and technology transfer literature (Ancona & Caldwell, 1992; Cooper, 2001; Kim & Wilemon, 2007; Tushman, 1978). Project structures for these roles are typically temporary in duration, associated with change-oriented initiatives, and involve teams that are cross-functional in composition. The literature suggests that structural requirements for projects must vary to achieve technical and organization effectiveness and that the most common proxy for project performance is conformance to cost, schedule and quality objectives. Over time, research has linked project performance with a variety of structural attributes such as locus of control, team composition, decentralization, and informational configurations (Allen, 1977; Barley, 1990; Barzak and Wilemon, 1990; Lawrence, 1997; Tushman, 1978). However, with a few notable exceptions (Caldwell & O'Reilly, 2003; Doolen, Hacker & Van Aken, 2003; Drach-Zahavy & Somech, 2001; Keller, 200, 2006; Lee, Pelz & Andrews, 1962), there is a scarcity of research to substantiate the effects of behavioral attributes on technological project performance.

In the present research we investigate several behavioral aspects of technology transfer project effectiveness. Specifically we test the significance of training, perceived technology strategy, task significance and work satisfaction as antecedents of project effectiveness. We believe that behavioral inquiry will add substantial understanding to the management of innovation and technology transfer projects and that "people" issues will account for variance unexplained by more tangible notions of structural or technological configurations. We draw from the fields of organizational psychology and small group management to pose relationships relevant to the management of technology transfer projects. We incorporate a unique sample of Japanese project teams that are developing new manufacturing processes and technologies for deployment to various global production operations. We believe the results of our study are pertinent to organizations that increasingly rely on project teams to build sources of innovation for competitive advantage (Bawdawy, 1991; Clark and Fujimoto, 1989).

Japanese companies instituted manufacturing innovations that for years led world-class standards of excellence (Jackson & Debroux, 2008). Benchmark concepts such as the Toyota Production System, quality circles, zero defects and kaizen systems of continuous improvement are often viewed as cultural manifestations that were born in Japanese organizations as small group or project team implementations (Bird, 2002; Clark & Fujimoto, 1989; Trott, 2008). These Japanese groups reflect a collectivist perspective stemming from the centuries-old Confucian influence pervasive throughout East Asia ((Hofstede, 1980; Levinson & Christensen, 2002). Collectivism is a cultural mind-set that prioritizes the value of relationships and reciprocity between group members. Collectivism is the opposite notion of individualism where group ties are less important and self-interest is the prevalent norm. Collectivism embraces norms distinguished by tight interpersonal ties and group-derived value systems. Hofstede's research found that Japan ranked among the highest of all cultures on collectivism.

Collectivism poses interesting behavioral attributes that might impact technology transfer project outcomes. For example research has linked group effectiveness with collectivist notions of cohesion (Hambrick, 1995), coordination (Guastello & Guestello, 1998), cooperation (Wagner, 1995), group emotion (Barsade and Gibson, 1998), and collective efficacy (Bandura, 1997). Furthermore, collectivism can be associated with such productive behaviors as cooperation, self-effacement, and the preservation of "face" in relationships (Flowerdew, 1998). Cooperation should facilitate goal accomplishment and reciprocal good-will between team members while self-effacement promotes a demeanor of personal humility to lessen team conflict and hostility. In addition, team member concerns to save face helps build personal accountability and a team atmosphere of trust. The present research, therefore, views Japanese teams as a particularly interesting setting for the behavioral side of technology transfer research.

The following sections describe a test of several behavioral antecedents on project effectiveness within the collectivist setting of Japanese project teams. The first section describes the research model of project effectiveness as it is related to the independent variables of satisfaction, training, perceived technology policy. Task significance is depicted as a moderating

variable in the model. A methodology section then discusses the data sample and relevant hypothesis testing procedures. Results of the tests are then presented and the ensuing discussion section relates implications of the findings for the broader body of literature. In the concluding section, directions for future research are suggested.

THEORETICAL DEVELOPMENT

Socio-technical theory (Emery & Trist, 1965) is a seminal facet of organizational science that views work design as a complex interaction between technology and social systems within the workplace. While most early theorists viewed technology as a structural or an organizational-level contingency (Woodward, 1958; Burns and Stalker, 1961; Thompson, 1968), socio-technical theorists emphasized the interrelatedness of human and technical factors in organizations. Socio-technical theory clearly distinguished the behavioral aspects of human resources as they faced technological challenges in their job environments. Technology was viewed not only as a way of accomplishing work but also of designing new or innovative work processes to enhance performance of organizations. Socio-technical research viewed organizational performance at the individual, group or organizational level as the joint optimization of both technology and human behavior.

A key notion of the socio-technical perspective is the need to design work to align human factors with respect to the relevant technological environment. Specifically, both economic performance and job satisfaction depend upon the goodness of fit between an organization's social and technical systems (Trist, 1982). Other important principles of socio-technical theory include the idea that work is system of activities performed by groups as opposed to individuals. Self-regulation is a hallmark for work group functionality as opposed to externally-imposed constraints. Work roles should be discretionary as opposed to prescribed, and individuals should complement technology as opposed to being a secondary consideration of technological deployment. .

The present research employs these perspectives as a behavioral foundation for assessing individual-level phenomena as related to the environments of Japanese technology transfer teams. It draws from prominent sociotechnical themes such as work design (Hackman and Oldham, 1976), job enrichment (Orpen, 1979), employee satisfaction (Locke and Latham, 2006), and self-regulating work groups (Cummings, 1978; Rousseau, 1977). Specifically, we hypothesize relationships incorporating training to reflect an aspect of work design, task significance as a component of job enrichment, employee satisfaction, and perceived technology policy as a job design attributes of self-regulating work groups. We suggest that these variables influence project group individuals in such a way to significantly impact their technical work and project outcomes. We also recognize that the Japanese sociotechnical setting offers a distinctive perspective of project performance within its idiosyncratic collective culture (Westney, 1985).

Figure 1

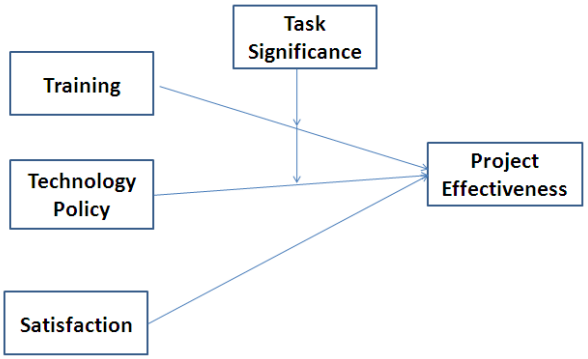


Figure 1 summarizes the research model adopted in our present study. The model suggests a direct influence of three behavioral factors (training, perceived technology policy, and task satisfaction) on project effectiveness. It further implies a moderating effect of task significance to explain additional variance of the training and technology policy relationships.

Project Effectiveness

"Project effectiveness" is the degree to which technology transfer teams meet their expected goals and objectives for a particular innovation project. A traditional proxy of project effectiveness is adherence to schedule, budget and performance objectives (Katz, 1982; Keller, 1986; Clark, 1989). Such a goal oriented approach to project performance measurement is valid for a number of reasons. Projects are typically one-time endeavors with little precedent for more concrete, task-specific measures of accomplishment. Therefore project goals and objectives constitute the standard performance baselines in professional practice of project management (PMBOK, 2006). For technology transfer projects, however, objectives are particularly subject to change and difficult to meet due to the inherent uncertainty and ambiguity of its environment (Daft and Lengel, 1986). As a result, project effectiveness should vary considerably across projects and serve as a suitable criterion for the present study.

Task Satisfaction

"Task satisfaction" is defined as a project individuals' level of gratification or fulfillment associated with their project's work environment. Answering calls for further studies on the satisfaction to performance relationship (Judge, Thoreson, Bono, & Patton, 2001), this research explores task satisfaction and project effectiveness from a socio-technical project perspective. Considerable debate in the literature questions the overall predictability of job satisfaction on

task or job performance. While studies up to 10-15 years ago tended to show a tenuous relationship between job satisfaction and performance (c.f., Brayfield & Crockett, 1955; Iaffaldano & Muchinsky, 1985; Petty, McGee, & Cavender, 1984; Vroom, 1964), recent meta-analyses have shown stronger evidence for the satisfaction to performance relationship (Edwards, Bell, Arthur, & Decuir, 2008; Harrison, Newman, & Roth, 2006; Judge et al., 2001). For instance, Judge et al. (2001) in a meta-analysis on 312 samples and an *N* of over 54,000, found the mean true correlation between job satisfaction and job performance to be an estimated .30.

Other conceptualizations of the satisfaction to performance relationship have defined performance in terms of task and context (Edwards et al., 2008; Organ, 1988) and looked at the facet level of job satisfaction (Edwards et al., 2008). In fact, one of the facets specifically delineated is satisfaction with job-related tasks. Edwards et al. (2008), in their study of 440 manufacturing plant employees, examined facets of job satisfaction with both task and contextual performance. Their work argued and found that "due to the multidimensional nature of job satisfaction and job performance, there are differential relationships between facets of job satisfaction and dimensions of performance" (p. 444). Their study showed a significant relationship between satisfaction with work (task satisfaction) and task performance, but lacked a relationship with contextual performance. In addition, Mason and Griffin (2002) argue for a satisfaction construct that is targeted to the task versus the job. They contend that while individuals in groups may have responsibilities that fall outside the scope of the task being accomplished (e.g., job duties), the common effort of each individual is focused on the task at hand. A direct relationship is expected between task satisfaction and project effectiveness.

H1: Task satisfaction will influence project effectiveness in a direct positive relationship.

Training

"Training" refers to the level of emphasis firms place on instructional interventions to enhance innovation, technology transfer, or project team processes. Campion, Medsker, and Higgs (1993) identified training as a significant correlate of work group effectiveness. From the socio-technical perspective, training programs might be used to focus a team's innovative philosophy, enhance creativity, expand technical knowledge, or sharpen decision-making and interpersonal skills. Since projects are typically executed by cross-functional groups, team building training might have particular relevance in the present study. Team performance has been specifically linked to various team building instruction such cross training (to learn other team member skills), coordination and adaptation for increasing team efficiencies, and team self-correction for effectively diagnosing and solving problems (Hollenback, DeRue & Guzzo, 2004; Marks, Sabella, Burke & Zacccaro, 2002; Salas, Nichols & Driskell, 2007).

Campion and colleagues (1993) noted that prior support for the overall significance of team training was mixed, that methodologies of most studies had been weak, and that most studies were focused on process, rather than performance, outcomes. However, more recent work has specifically focused on training at the individual level and its contribution to team-related performance criteria. Training strategies focused on group coordination and adaptations have yielded measureable team performance improvements (Burke, Steel, Pierce & Kendall, 2006; Salas et al., 2007), suggesting that individuals contribute more to their team when prepared to be flexible and adaptive within the ambiguous context of technological change. Training for creativity and idea generation has produced intermediate benefits for the problem solving challenges of technology transfer teams. Baruah and Paulus (2008) demonstrated a positive effect of training on the total number and originality of ideas generated by group individuals. Their evidence corroborates prior findings that suggest training techniques enhance creativity or attitudes toward creativity at both the individual (Basadur, Runco & Vega, 2000; Puccio, Firestien, Coyle and Masucci, 2006) and group levels (Firestien, 1990).

H2: Training will influence project effectiveness in a direct positive relationship.

Perceived Technology Policy

"Perceived Technology Policy" is the degree to which individuals believe technology is emphasized in a company's strategic initiatives and the degree that organizational capabilities are deployed to facilitate creativity, innovation and entrepreneurship. Porter (1985) argued that managers should actively incorporate technology strategies that address which technologies to develop, evaluate choices between technology leadership and follower-ship roles, and actively assess technology licensing, both inbound and outbound. According to Kantner (1988), technology policy should foster capabilities to explicitly define a technology transfer strategy, actively assess its entrepreneurial talent, break down functional barriers, and elevate innovative projects to the highest priority. Burgelman, Kosnik, and Von den Poel (1988) discussed management's capacity to articulate substantive technology development strategies, to assess the strategic importance of entrepreneurial initiatives, and to define the relatedness of those initiatives to the business unit's core capabilities.

Research has linked technology policy with organizational performance. Aiken and Hage (1971) supported a positive correlation between innovation and the presence of specialization and decentralization, constructs drawn from the Burns and Stalker (1961) model of organic technology policy. Ettlie (1983) found that aggressive technology policy was a predictor of innovation implementation rates. Similarly, Godkin (1988) linked performance with project management capabilities such as planning, scheduling, and control, elevation of science and technology to high levels of visibility, and the implementation of explicit project investment decision criteria. An additional study found a positive moderating effect of overall business

strategy on the relationship between technology and firm performance (Zahra & Covin, 1995). As distinguished by Bower (1978), the value of management support or leadership's explicated policy is clearly moderated by users' perception of that support or policy. This evidence suggests that to the degree individuals perceive clearly-defined technology policies and relevant organizational support, their performance of technology transfer and innovation tasks result in superior performance.

H3: Perceived technology policy will influence project effectiveness in a direct positive relationship.

Task Significance

"Task significance" is the extent to which an identifiable piece *of work (job)* affects or is important to others within or outside the *organization.* Both job design (Hackman & Oldham, 1975, 1976, 1980) and social information processing theory (Salancik & Pfeffer, 1978) infer that employees who perceive value in their jobs (high task significance) display higher job performance. Campion et al., 1993) in a study of 391 employees and 70 managers, investigating relationships between 19 separate work group characteristics and both subjective and objective criteria of effectiveness found that "job design characteristics were very useful in predicting effectiveness" (p. 840). In fact, task significance was significantly related to two of the three criteria of work group effectiveness. Grant (2008) argues that one of the limitations of past research on task significance is "failing to isolate task significance as an active ingredient responsible for increases in job performance" (p. 108). Grant (2008), using three separate experiments, found that task significance increased performance levels of fundraising callers, increased job dedication and helping behavior of lifeguards, and higher fundraising performance when callers received task significance cues. Dwyer and Fox (2006) tested the job demands (role, workload, and work pace) to performance relationship moderated by job resources (task significance being one of the seven job demands). Following the lead of task significance research and based on literature supporting the performance effects of training and technology policy, we explore the interactive effect of both training and technology policy with task significance on effectiveness. Therefore, it is hypothesized that:

H4: The relationship between training and perceptions of group effectiveness will be moderated by task significance in such a way that the relationship will be stronger when there are high levels of task significance then when there are low levels of task significance.

H5: The relationship between technology policy and perceptions of group effectiveness will be moderated by task significance in such a way that the relationship will be stronger when there are high levels of task significance then when there are low levels of task significance.

METHODS

The sample consisted of primary data collected directly from project team personnel developing manufacturing processes (Teasley and Robinson, 2005). The project teams were based in Japan, were entrepreneurial within the context of large organizations, cross-functional in composition, and supported manufacturing divisions with the development of new technical applications or process technologies. The sample consisted of 81 individuals (n=8) in 27 project teams located in six large Japanese corporations. The companies corresponded to U.S. SIC categories 371 (motor vehicles and equipment), 362 (electrical industrial apparatus), 379 (miscellaneous transportation equipment), 3569 (general industrial machinery), and 7371 (software programming, systems analysis and design).

Data were collected in Japan with a 91-item questionnaire that addressed the participants' work during the prior nine weeks. The questionnaire was a summary instrument that capped a nine-week longitudinal analysis of project team communication patterns. Variables of interest for the present study were measured at the individual level with multi-item subjective scales to assess each of the independent and dependent variables as well as the proposed moderating variable. The Likert-type scales addressed work tasks and perceived project environments over the entire eight-week period. An additional section was included in the individual questionnaire that collected demographic information about the respondents.

This study's primary investigator spent extended time in Japan to arrange data sites, oversee date collection, and reduce non-response bias through the use of personal contacts and a hierarchical approach to enlist participants. An established relationship with Japan's Industrial Robotics and Factory Automation Center (IROFAC) was leveraged to secure cooperation from nine of IROFAC's member companies. Management-level employees of nine companies responded positively to IROFAC's solicitation and each offered an average of three appropriate projects for study. PI met personally with each individual to address their questions or concerns and to prepare and instruct them for administration of the instrument. These individuals then required that all project team members complete the research instruments and return to them for processing. Since data collection was administered as a hierarchical mandate, there was minimal incidence of non-response bias.

Prior to administration, all construct items were prescreened by knowledgeable practitioners to assure face validity of the measures and appropriateness of the collection methodology. Any questionable measures were modified to address reviewer comments. The instruments were then translated from English by a qualified bi-lingual Japanese native. The translated instruments were further refined by a six-person Japanese/English bilingual panel to strengthen their cross-cultural equivalence (Bensaou, Coyne & Venkatraman, 1999; Douglas & Craig, 1983; Knight, 1997). The panel review was a complicated procedure where an item-by-item analysis rated the perceived equivalence between each English and Japanese item-pair. Individual item-pairs were progressively modified through discussion until a full-panel

consensus was achieved. This procedure is advocated by Riordan and Vandenberg (1994) who maintained that focus groups more precisely validate conceptual equivalence than the commonly utilized practice of back-translation. The power of focus groups, claim the authors, is that researchers can flesh out construct meaning from a wide perspective and interactively derive group consensus on an item-by-item translation.

An extensive literature search produced previously reliable and conceptually suitable scales for three of the five required variables. Modifications of existing scales were combined with new items for the two remaining variables, and then all items were randomized for inclusion in the research questionnaire. The following paragraphs describe operationalization of each research variable.

Early scholars noted particular difficulty in measuring effectiveness within research and development environments (Allen, 1977; Whitley & Frost, 1971). Because of the vague and uncertain nature of R&D work, typical hard measures such as ROI are difficult to apply. However, more explicit proxies have been generalized for project effectiveness that reflect conformance to cost, schedule and technical performance goals. These goal-oriented proxies have been employed satisfactorily within R&D work, which relies heavily on project structures and processes (Keller, 1986, 1994; Tushman, 1978). Project effectiveness in the present study was operationalized with seven items addressing specific perceptions of schedule and budget slippage and, as a measure of technical performance, the amount of task or job rework required for the project.

Task satisfaction is frequently considered a criterion variable. For the present study, however, it is hypothesized as an antecedent to project effectiveness. Job or individual satisfaction is frequently related to performance both as a predictor of individual innovativeness (Hage & Aiken, 1967; Pierce & Delbeq, 1977) and as an antecedent of effective group process (Aryee & Leong, 1991; Greenbaum, Kaplan & Metlay, 1988). Qualified researchers have argued that single-item measures of the construct are equally as reliable as the broad range on multi-item assessments found in the literature (McGehee & Tullar, 1979; Weaver, 1980). The present study adopted a three-item measure. Each item probed distinctive aspects of satisfaction: satisfaction with one's own work during the eight-week period, satisfaction with the group's work, and one's perception of the group's satisfaction.

In their pervasive review of the group literature, Campion et al. (1993) used group context as one category of variables to organize existing research on small group effectiveness. Group context includes influences that stem from outside group boundaries and impact the degree to which teams achieve their work-related goals. In the present study, both technology policy and training were considered contextual variables that are important within the scope of technology transfer. Technology policy should reflect the degree a parent company or division relies on a well-defined set of strategies for the pursuit, development and implementation of technological opportunity. Two sources provided items for the technology policy scale. Two of the items drew from Ettlie's operationalization of a technology policy construct that achieved a reliability of Cronbach alpha = .78 Ettlie, 1983; Ettlie, Bridges and Okeefe, 1984). A third item was borrowed

from Burgelman's innovative capabilities audit (Burgelman et al., 1988). The latter item was theoretical and had not been previously tested for reliability. However, as described in the results section, the items demonstrated tight reliability and factor structure for the present dataset.

Campion et al. (1994) also discussed job design as a prevailing theme within the work group literature. Task significance was an aspect of job design utilized in the present study. Task significance was hypothesized to moderate the contextual variables since project members would be more motivated in uncertain R&D environments when they better understood the importance of their project work outcomes to the larger organization. The three-item task significance measure was borrowed from Campion et al. (1994) inventory. Their preliminary study evidenced an internal reliability of .74 for the measure.

RESULTS

Principal components analysis showed all items loaded on their respective factors, confirming convergent validity of the factors. Table 1 indicates that Cronbach's alpha values for all variables except project effectiveness were acceptable demonstrating Chronbach's coefficient alpha reliabilities greater than 0.7 (Churchill, 1979). Project effectiveness, on the other hand, only achieved an alpha score of .66. According to Nunnally (1978), reliabilities slightly less than .7 are justified in data that is exploratory in nature. In our case, we feel that the cross-cultural challenges are sufficiently qualify the exploratory nature of this study; this is the first study to use the effectiveness scale in a Japanese setting Summated scores of the multi-item scales were computed, which per Baron and Kenny (1986), were then mean centered to avoid multi-collinearity.

Table 1: Scale Items and Reliabilities

Variable/Item (All scales are seven point scales)	Cronbach's Alpha (α)
Training: (Do not agree at all . Completely agree) • Our company actively retrains our engineering, production, and marketing personnel regarding latest scientific and R&D developments • Our company provides out team with quality control and customer service training, which is superior to other companies • Our company provides team skills training (project management, communication, etc.), which is more than adequate	0.71
Perceived Technology Policy: (Do not agree at all … . Completely agree) • Our team is familiar with technological forecasting and the technological developments of our competitors • Our team is encouraged to develop specialized technological capabilities which are unique in the industry • Our team adheres to a very clear technological policy • Our management encourages our team to search broadly for technological opportunities	0.71

Table 1: Scale Items and Reliabilities	
Variable/Item (All scales are seven point scales)	Cronbach's Alpha (α)
Task Significance: (Do not agree at all … Completely agree) • The work performed by our team is important to our customers and to our industry • Our team makes an important contribution to serving other departments of this company • Our team is a very important and a legitimate part of this company • The work of this team contributes to the advancement of science and engineering	0.76
Project Effectiveness: (Do not agree at all Completely agree) • Many of our tasks were accomplished behind schedule (R) • Our team has significantly exceeded its budget during the last eight weeks (R) • As a team, we have accomplished our goals projected for this period • There has been an unusually large amount of unplanned rework and redesign (R)	0.66
Satisfaction: (Not at all satisfied … . Completely satisfied) • How satisfied are you with your own task accomplishments during the last eight weeks? • How satisfied are you with your overall team's task accomplishments during the last eight weeks? • How satisfied would you say that your entire team is with its task accomplishments during the last eight weeks?	0.89

The hypotheses were tested using multiple regression in SPSS. In the first step, the dependent variable, effectiveness, was regressed on the three independent variables, training, technology policy, task significance, and task satisfaction. The main effects model was significant at the 0.000 level with the four independent variables explaining 37% of the variance in the dependent variable, project effectiveness. The interaction terms were introduced in the second step. This interaction model was significant at the 0.000 level, yielding an r-squared of 0.47. Thus the interaction accounted for 10% variance of the dependent variable. No multi-collinearity with all VIF 1.7 or less, well below 10, the flag for multi-collinearity.

Regression results provided support for three of the five hypotheses as indicated in Table 2. A t-value of 5.14 and a significance level of 0.001 indicate strong support for the direct positive relationship predicted between task satisfaction and project effectiveness in H_1. In support of the previously cited literature, project effectiveness increases with the level of task satisfaction of team members. Although the main effect of training on project effectiveness (H_2) was not significant (b = -0.073; p = 0.36), as hypothesized in H_4, the relationship between training and effectiveness does become stronger with increase in perceived task significance (b = 0.24; p=0.01). That is, task significance moderates the relationship between training and project effectiveness, as hypothesized in H_4.

Technology Policy positively and directly influences project effectiveness as per H3 (b = 0.21; p = 0.04). Perception of a technology oriented policy itself tends to increase perceived project effectiveness. Task significance doesn't appear to play a role in this relationship. The strengthening of the relationship between technology policy and project effectiveness with increase in perceived task significance was tested in H_5, which was not supported. While the

main effect between technology policy and project effectiveness in the moderated model continued to be positive, the interaction between task significance and technology policy was not significant (b = -0.01; p = 0.89).

Table 2: Hypotheses Tests			
Hypothesis	B	t	Sig
H_1: Task Satisfaction ⟶ Project Effectiveness	0.45	5.14	0.00**
H_2: Training ⟶ Project Effectiveness	-0.073	-.92	0.36
H_3: Technology Policy ⟶ Project Effectiveness	0.21	2.14	0.04*
H_4: Training x Task Significance (TS) ⟶ Project Effectiveness	0.24	3.13	0.00**
H_5: Technology Policy x TS ⟶ Project Effectiveness	-0.01	-0.17	0.89
Note: * significant at the 0.05 level ** significant at the 0.00 level			

DISCUSSION

Our findings are summarized in Table 2. H1 hypothesis proposed that task satisfaction would demonstrate a positive effect on project effectiveness, and our data substantiated this relationship. Socio-technical theory clearly implies that human satisfaction eases technological adoption in organizations and our data supports that notion. The results suggest a general congruence between the technical and social subsystems within these organizations (Emery and Trist, 1965) and a fulfillment of respondents' social/psychological needs as they were engaged in technologically intense environments. As reflected in the research of Bostrom, et al (2009), technical subsystems consist of business processes and their supporting technologies while social subsystems are comprised of the relevant individuals and the needs, skills, attitudes, values, they bring to the work environment. Task satisfaction in our sample reveals the extent that respondents felt positive about their personal attributes and contributions to their collective group settings. Technology transfer environments include ambiguous tasks and sometimes intimidating team challenges. These results imply that the task satisfaction of individuals mitigates potential counter-productive outcomes of these environments. The findings also lend credence to the satisfaction construct as an apriority, antecedent influence on effectiveness (Edwards, Bell, Arthur, & Decuir, 2008; Harrison, Newman & Roth, 2006; Judge et al., 2001).

Hypothesis H2 did not support the notion that training will influence project effectiveness in a direct, positive relationship. A socio-technical mindset would influence managerial design of relevant team- and individual-level training to facilitate the effectiveness of new technological environments. Such training would ideally impart technical knowledge and also facilitate human team processes (Hollenbeck et al, 2004). Training would help to reduce the uncertainty of new technology and strengthen the tolerance for ambiguity (Teasley et al, 2005, Salas et al, 2007). The present data, however, failed to produce significant support for this perspective. Perhaps Japanese managers depend less on focused (training than on knowledge gained through job

rotation and continuous learning techniques Nonaka and Takeuchi, 1996). Another explanation concerns the limited longitudinal scope of the data sample. Since data specifically addressed only a nine week time frame, the full effects of any training initiatives may not have been realized in such a short period of operation. A follow-up study utilizing a greater longitudinal period and a cross-cultural sample might rectify these concerns and clarify and more objective assessment of the hypothesized relationship. Interestingly, as discussed below, testing the moderation of task significance on training did produce the expected performance affect.

Hypothesis H3 was supported suggesting that perceived technology policy is a positive influence on project effectiveness. Socio-technical theory validates this finding given the priority it places on intrinsic motivational factors and humanistic work designs to shore up the technological work efforts (Hackman & Oldman, 1976; Passmore,2006). Sound technological policy would include efforts to explicitly design work that it is compatible with the idiosyncratic demands of technology. Hackman and Oldman sparked a stream of research associating positive behavioral outcomes with various aspects of technical work design utilizing such attributes as structure, process, rewards and incentives. Passmore (2006) described sound technology policy as the delegation of control over task material and processes; reward systems linked to individual-level task outcomes; institutionalization of task variety and learning opportunities; and task design that links individual tasks to the overall firm strategy. Our findings reflect technology policy as a viable force for human effectiveness when its components are clearly explicated and their value clearly understood by project individuals. Managers should clear articulate their technology policies assure their visibility and support throughout the organization. Individuals are motivated by a clear vision of their firm's technological priorities and how their work fits into the bigger picture.

Hypotheses 4 and 5 posed moderating effects of task significance both on training and technology policy. The moderating effects were hypothesized to increase the direct influence effects of each of these dependent variables project effectiveness. Task significance would be an integral consideration for socio-technical work designers who recognize the variable's intrinsic motivational potential. Team members would be more motivated as they better understand the broader impact of their technological tasks to overall organizational goals. In the case of training (Hypothesis 4), the moderating interaction produced a positive effect on project effectiveness while single effect of training as an independent variable did not. This is an interesting outcome suggesting that training is more potent when its outcomes are explicitly associated with strategic goals of the firm. Trainees would then view their efforts as more significant to higher-level outcomes in their firm. This finding is consistent with prior job design research (Hackman & Oldham, 1975, 1976, 1980) substantiating that employees who perceive value in their jobs (high task significance) display higher job performance.

Concerning technology policy (Hypothesis 5), the expected interaction of task significance was insignificant with respect to project effectiveness. This was an interesting discovery since task significance clearly aligns with the central themes of socio-technical theory.

Because technology policy in this study is a perceptual interpretation, it may already incorporate the variance that might otherwise be explained by task significance. Investigation of the data's correlation matrix corroborates this perspective, demonstrating an average correlation of .30 between the two sets of items.

IMPLICATIONS

This study extends scholarly work on innovation and technology management from a humanistic perspective. It also provides useful findings for the community of practitioners that struggle with increasingly competitive, technology – driven competitive environments. In addition, it offers a small window to the idiosyncratic nature of Japanese engineering cultures. Implications are noted below in three areas of scholarly and practical interest. The first section notes the study's empirical validation of socio-technical theory. The second set of implications denotes the practical importance of managers emphasizing enlightened human resource approaches when developing their organizations' innovative capabilities. The third set of implications reflects lessons to be learned from the competitive practices of Japanese technology transfer.

The intensity of today's competitive environments pressures organizations to leverage technology in ways that are both innovative and dynamic (Kanter, 1988; Grove, 2010). As one avenue of leverage, we have suggested socio-technical theory as a fruitful paradigm for organizing research of technology-based work teams. In this study we focused on a few group and organizational variables, and have reinforced the notion that two ingredients for sustainable technological advantage are a) a profound emphasis on human behavior (Keller 1997, 2006), and b) an organizational context that encourages technologically supportive policies and procedures (Doolen, Hacker & Van Aken, 2003) . We build on existing socio-technical authors to identify technology transfer variance explained by appropriate behavioral and contextual influences. Our work demonstrates the viability of project teams as an essential human resource vehicle to sustain technology transfer as an innovative capability. The cohesiveness and focus of these teams are best understood through the scholarly lens of organizational behavior. We encourage future studies of technology and innovation management to incorporate the valuable lessons of organization/human psychology.

Practitioners of project and technology management should note the socio-technical lessons of work design. Technological work in organizations is performed predominately by engineers and technically trained individuals. This category of workers sometimes lack effective people skills and a basic understanding of organizational psychology. To embrace a socio-technical view, their managers should plan and compensate for these deficiencies by incorporating appropriate training and development strategies to reinforce the human side of technology. Managers should plan for team-building interventions that focus not only on team processes, but make visible the significance of engineering projects. They should also offer adequate intrinsic support to enhance the overall satisfaction of their workers. Some of today's leading technology companies such as

Google and Apple Computer are well-noted for their intrinsic benefits offered to attract, develop and maintain some of the world's brightest technical teams. This study discusses a few important approaches for managers to enhance the technology transfer effectiveness of their teams.

For nearly have a century Japan has enjoyed global economic leadership derived from its foundations in technology and innovation. International surveys of R&D productivity in the US and Japan indicate a greater rate of R&D knowledge flows and spillovers in Japan (Cohen, Goto, Nagata, Nelson and Walsh, 2002). This outcome has been attributed in part to a collectivist style of project management that enhances a unique alignment among team process, human capacity and technology development (Clark and Fujimoto, 1989). Japanese firms continue to innovate through a national collaborative system fostering human collaboration beyond the boundaries of single firms (Wen and Kobayashi, 2001) and research has documented a high diffusion of innovative Japanese organizational routines and management practices (i.e. capabilities) to Western firms (Massini, Lewin, Numagami, Pettigrew (2002). The present study discloses a fine-grained view of Japanese technological teams in action. At this level of detail, certain facets of their socio-technical dynamics have become more transparent, yielding better understanding of Japanese behavioral characteristics.

LIMITATIONS AND FUTURE RESEARCH

Some limitations of this study have been noted in previous reports of the data (Teasley and Robinson, 2006; Teasley, Kodama and Robinson, 2009). Perhaps the most significant methodological limitations concern the data and its collection in Japanese companies. Survey research raises unique challenges in a cross-cultural context, particularly with instruments translated from English to a language as dissimilar as Japanese. The author made significant efforts to ensure conceptual equivalency and to test for equivalency in the original study, but cannot ascertain with full confidence that English-derived concepts were fully captured in the Japanese version. The sample was not random but rather a convenience sample developed hierarchically (within several of the companies) as a work directive from managers of significant rank in their divisions. Therefore the data do not fully represent a statistical population, and are limited to Japanese participants with only restricted generalizability across cultures.

As noted in the Implications section, we believe this study to be a significant contribution to the technology and innovation literature, and to provide a practical guidance to technology transfer managers. The study is worthy of replication in additional cultures as the sophistication of R&D spreads globally. We also believe that human factors facet of R&D management lacks thorough understanding and is a ripe venue for future research. We also encourage additional Japanese project-level studies such as those conducted by Song and Parry (1997) to seek cultural lessons for creating and deploying new innovative technologies.

REFERENCES

Aiken, M. and G. Hage (1971). The organic organization and innovation. *Sociology*, 5: 63-82.

Allen, T.J. (1977). *Managing the Flow of Technology: Technology Transfer and the Dissemination of Technological Information Within the R&D Organization* (Boston: MIT Press).

Ancona, Deborah G. and David F. Caldwell (1992). Demography and design: Predictors of new product team performance. *Organization Science*, 3(2), 321-341.

Andrews, F. and G. Farris, (1967). Supervisory practices and innovation in scientific teams. *Personnel Psychology*, 20(4), 497-515.

Andrews, F. and G. Farris, (1972). Time pressure and performance of scientists and engineers. *Organizational Behavior and Human Performance*, 8(2), 185-200.

Aryee, S. and C. Leong (1991). Career orientations and work outcomes among industrial R&D professionals. *Group and Organization Studies*, 16(2), 193-205.

Badawy, Michael 1991. Technology and strategic advantage: Managing corporate technology transfer in the USA and Japan. *Engineering Management Review*, Summer, 63-69.

Bandura, A. (1997). *Self-efficacy: The Exercise of Control*. New York: W.H. Freeman.

Barley, S.R. 1990. The alignment of technology and structure through roles and networks. *Administrative Science Quarterly* 35, 1: 61-103.

Barney, J. (1991). Firm resources and sustained competitive advantage. *Journal of Management*, 17, 99-120.

Baron, Reuben and David Kenney (1986). The moderator-mediator variable distinction in social psychological research: Conceptual, strategic, statistical considerations. *Journal of Personality and Social Psychology*, 51(6),1173-1182.

Barsade, S. and D. Gibson (1998). Group emotion: a view from the top and bottom. In D.H. Gruenfeld and Colleagues (Eds), Composition. *Research on Managing Groups and Teams.* Vol 1: 81-102, Stamford, CT: JAI Press.

Baruah, J. and P. Paulis (2008). Effects of training on idea generation in groups. *Small Group Research*, 39, 523-524.

Barzak, Gloria and David Wilemon 1991. Communicaitons Patterns of New Product Development Team Leaders. *IEEE Transactions of Engineering Management*, 38, 2: 101-109.

Badawy, Michael (1988). What we have learned about managing human resources. *Research-Technology Management*, September-October, 19-35.

Badawy, Michael (1991). Technology and strategic advantage: Managing corporate technology transfer in the USA and Japan. *Engineering Management Review*, Summer, 63-69.

Basadur, M., Runco, M. A., & Vega, L. A. (2000). Understanding how creative thinking skills,attitudes and behaviors work together: A causal process model. *The Journal of CreativeBehavior, 34*, 77-100.

Bird, A. (Ed.) (2002). *Encyclopedia of Japanese Business and Management* (London: Routledge).

Bensaou, M., Coyne, M., and Venkatraman, N. (1999). Testing metric equivalence in cross-national strategy research: An empirical test across the United States and Japan. *Strategic Management Journal*, 20(7), 671-689.

Bostrom, R., Gutpa, S and D. Thomas (2009). A Meta-theory for understanding information systems within Sociotechnical Systems. *Journal for Management Information Systems*, 26, 1, 17-47.

Bower, J. L. *Managing the Resource Allocation Process: A Study of Corporate Planning and Investment*. Boston, Mass.: HBS Division of Research, 1970

Brayfield,, A. H. and W. C. Crockett (1955). Employee attitudes and employee performance.*Psychological Bulletin*, (52), 5 396-424.

Burgelman, R.A., Kosnik, T.J and M. von den Poel (1988). Toward an innovative capabilities audit framework. In Burgelman R.A. and M.A. Maidique Eds., *Strategic Management of Technology*. 31-44, Homewood: Irwin.

Burke, S., Steel, K., Pierce, L. and D. Kendall (2006). Understanding team adaptation: A conceptual analysis and model. *Journal of Applied Psychology*, 87(1), p.3.

Burns, T. and G.M. Stalker (1961). *The Management of Innovation.* London: Tavistock.

Bushe, Gervase and A. Lea Johnson (1989). Contextual and internal variables affecting task group outcomes in organizations. *Group and Organization Studies*,14(4) 462-482.

Caldwell, D. and C. O'Reilly (2003). The determinants of team-based innovation in organizations: The role of social influence. *Small Group Research*, 24, pg 497.

Campion, M., Medsker, G., & Higgs, A. (1993). Relations between work group characteristics and effectiveness: Implications for designing effective work groups. *Personnel Psychology*, 46(4) 823-850.

Chan, J., Jiang, J. and G. Klein (2008). Team task skills as a facilitator for application and development skills. *IEEE Transactions on Engineering Management*, 55(3), 434-441.

Clark, K.B. (1991). Project scope and project performance: the effect of parts strategy and supplier involvement on product development. *Management Science*, 35(10) 1247-1263.

Clark, K.B., and T. Fujimoto (1989). Lead time in automobile product development: Explaining Japanese advantage. *Journal of Engineering and Technology Management*, 6(1) 25-59.

Cohen, W., Goto, A., Nagata, A., Nelson, R. and J. Walsh (2002). R&D spillovers, patents, and the incentives to innovate in the Japan and the US. *Research Policy*, 31(8/9), p. 1389

Cooper, R.G. (2001). *Winning at New Products. Accelerating the Process from Idea to Launch*. Cambridge, MA: Persens Publishing.

Cummings, T.G. (1978). Self-regulating work groups: A socio-technical synthesis. *Academy of Management Review*, 3(3), 625-634.

Daft, R. and R. Lengel 1986. Organizational information requirements, media richness and structural design. *Management Science* ,32: 554-571.

Doolen,T., Hacker, M. and E. Van Aken (2003). The impact of organizational context on work team effectiveness: A study of production teams. *IEEE Transactions on Engineering Management*, 50(3), 285.

Douglas, S.P., and Craig, C.S. (1983). *International Marketing Research*. Prentice-Hall, Englewood Cliffs, NJ.

Drach-Zahavy, A. and A. Somech (2001). Understanding team innovation: The role of team processes and structures. *Group Dynamics: Theory, Research and Practice*, 5, 111-123.

Dwyer, D.J., & Fox, M.L. (2006). The relationship between job demands and key performance indicators: Moderating effects of job resources in call centers. *Journal of Business and Management*, 12(2), 127-145.

Edwards, B.D., Bell, S.T., Arthur, W., and Decuir, A.D. (2008). Relationships between facets of job satisfaction and task and contextual performance. *Applied Psychology: An International Review*, 57(3), 441-465.

Emery, F. and E.Trist (1965). The causal texture of organizational environments. *Human Relations*, 18, 21-32.

Ettlie, J. (1983).Organizational policy and innovation among suppliers to the food processing industry. *Academy of Management Journal*, 26(1), 27-44.

Ettlie, J., Bridges, W.P. and R.D. O'keefe (1984). Organization strategy and structural differences for radical versus incremental innovation. *Management Science* 30, 6: 682-695.

Farris, G. (1969). Some antecedents and consequences of scientific performance. *IEEE Transactions on Engineering Management*, 16, 9-16.

Farris. G. and R. Cordero, (2002). Leading your scientists and engineers. *Research-Technology Management*, November-December 2002.

Firestien, R. L. (1990). Effects of creative problem solving on communication behaviors in small groups. *Small Group Research, 21*, 507-521.

Flowerdew, Lynne (1998). A cultural perspective on group work. *ELT Journal*, 52(4), 323-329.

Godkin, Lynn (1988). Problems and practicalities of technology transfer: a survey of the literature. *International Journal of Technology Management*, 3(5), 587-603.

Grant, A.M. (2008). The significance of task significance: Job performance effects, relational mechanisms, and boundary conditions. *Journal of Applied Psychology*, 93(1), 108-124.

Greenbaum, H., Kaplan, I. and W. Metlay (1988). Evaluation of problem-solving groups. *Group and Organization Studies*, 13(2), 133-147.

Grove, Andy (2010). How America can create jobs. *Bloomberg Businessweek Online*, July5, http://www.businessweek.com/magazine/content/10_28/b4186048358596.htm?chan=magazine+channel_top+stories.

Guestello, S. and D. Gustello (1998). Origins of coordination and team effectiveness: A perspective from game theory and non-linear dynamics. *Journal of Applied Psychology,* 83, 423-437.

Hackman, J.R., & Oldham, G.R. (1975). Development of the job diagnostic survey. *Journal of Applied Psychology*, 60, 159-170.

Hackman, J.R., & Oldham, G.R. (1976). Motivation through the design of work: Test of a theory. *Organizational Behavior and Human Performance, 16, 250-279.*

Hackman, J.R., & Oldham, G.R. (1980). *Work Redesign.* Reading, MA: Addison-Wesley. Hambrick, D. (1995). Fragmentation and other problems CEO's have with their top management teams. *California Management Review*, 37, 193-206.

Harrison, D.A., Newman, D.A., and Roth, P.L. (2006). How important are job attitudes? Meta-analytic comparisons of integrative behavioral outcomes and time sequences. *Academy of Management Journal*, 49(2), 305-325.

Hofstede. Geert (1980), *Culture's Consequences: International Differences in Work-Related Values*. (Beverly Hills CA: Sage Publications).

Hollenbeck, J., DeRue, D. and R. Guzzo (2004). Bridging the gap between IO research and HR practice: Improving team composition, team training, and team task design. *Human Resource Management*, 43(4), 353-367.

Iaffaldano, M.T., and Muchinsky, P.M. (1985). Job satisfaction and job performance: A meta-analysis. *Psychological Bulletin*, 97(2), 251-273.

Jackson, K. and P. Debroux, P. (2008). Innovation in Japan: an introduction. *Asia Pacific Business Review*, 14(3), 285-291.

Judge, T.A., Thoreson, C.J., Bono, J.E., and Patton, G.K. (2001). The job satisfaction-job performance relationship: A qualitative and quantitative review. *Psychological Bulletin*, 127(3), 376-407.

Kanter, R. M. (1988). When a thousand flowers bloom: Structural, collective and social conditions for innovation in organizations. In B. M. Staw and L. L. Cummings (eds.), *Research in Organizational Behavior*, 10, 169-211. Greenwich, CT: JAI Press.

Katz, R. (1982). The effects of group longevity on project communication and performance. *Administrative Science Quarterly*, 27, 81-104.

Keller, R.T. (1986). Predictors of the performance of project groups in R&D organizations. *Academy of Management Journal*, 29(4), 715-726.

Keller, R.T. (1994). Technology-information processing fit and the performance of R&D project groups: A test of contingency theory. *Academy of Management Journal*, 37(1), 167-179.

Keller, R.T. (1997). Job involvement and organizational commitment as longitudinal predictors of job performance: A study of scientists and engineers. *Journal of Applied Psychology*, 82(4) 539-545.

Keller, R.T (2001). Cross-functional project groups in research and new product development: diversity, communications, job stress and outcomes. *Academy of Management Journal*, 44, 3, 547-555.

Keller, R.T. (2006). Transformational leadership, initiating structure, and substitutes for leadership: A longitudinal study of research and development project team performance. *Journal of Applied Psychology*, 91(1), 202-210.

Kim, J. and D. Wilemon (2007). The learning organization as facilitator of complex NPD projects. *Creativity and Innovation Management*, 16(2), p.176.

Lawrence, B.S. (1997). The black box of organizational demography. *Organization Science.* 8, 1-22

Lee, S., Wong, P. and C. Chon (2005). Human and social capital explanations for R&D outcomes. *IEEE Transactions on Engineering Management*, 52(1), p.59.

Levinson, D., and K.Christensen (2002). *Encyclopedia of Modern Asia*, (157). Barrington MA.

Locke, E. and Latham, G. (2006). Work motivation and satisfaction: light at the end of the tunnel. *Psychological Science*, 1(4), 240-246.

Marks, M., Sabella, M., Burke, C. and S. Zaccaro (2002). The impact of cross-training on team effectiveness. *Journal of Applied Psychology*, 87(1), p. 3.

Massini, S., Lewin, K., Numagami, T. and A. Pettigrew (2002). The evolution of organizational routines among large Western and Japanese firms. *Research Policy*, 31(8/9), p.1333.

Mason, C.M., and Griffin, M.A. (2002). Group task satisfaction: Applying the construct of job satisfaction to groups. *Small Group Research*, 33(3), 271-312.

McGehee, W., and Tuller, W.L. (1979). Single-question measures of overall job-satisfaction: A comment on Quinn, Staines and McCullough. *Journal of Vocational Behavior*, 14, 112-117.

Nonaka, I and Takeuchi, H. (1996). A theory of organizational knowledge creation. *International Journal of Technology Management*, Vol. 11 Issue 7/8, 833-846.

Nunally, J.C. (1978). *Psychometric Theory*. New York: McGraw Hill.

Organ, D.W. (1988). A restatement of the satisfaction-performance hypothesis. *Journal of Management*, 14(4), 547-557.

Orpen, C. (1979). The effects of job enrichment on employee satisfaction, motivation, involvement, and performance: a field experiment. *Human Relations*, 32(3), 189-217.

Pelz, D,C, and F,M Andrews (1962). Organizational atmosphere, motivation and research contribution. *American Behavioral Scientist*, 6(4), 43-48.

Petty, M.M., McGee, G.W., and Cavender, J.W. (1984). A meta-analysis of the relationships between individual job satisfaction and individual performance. *Academy of Management Review*, 9(4), 712-721.

Pierce, Jon and Andre Delbecq 1977. Organization structure, individual attitudes and innovation. *Academy of Management Review,* 2, 1: 27-37.

Porter, Michael (1985). *Competitive Advantage*. New York: Free Press.

Puccio, G. J., Firestien, R. L., Coyle, C., & Masucci, C. (2006). A review of the effectiveness of CPS training: A focus on workplace issues. *Creativity and Innovation Management, 15*, 19-30.

Riordan, C.M., and Vandenberg, R.J. (1994). A central question in cross-cultural research: Do employees of different cultures interpret work-related measures in equivalent manner? *Journal of Management*, 20(3), 643-671.

Rousseau, Denise M. (1977). Technological differences in job characteristics, employee satisfaction, and motivation: A synthesis of job design research and sociotechnical systems theory. Organizational Behavior and Human Performance, 77(19), 18-42.

Rousseau, Denise M. (1985). Issues of level in organizational research: Multi-level and cross-level perspectives. *Research in Organizational Behavior*, 7, 1-37.

Salas, E., Nichols, D. and J. Driskell 2007. Testing three team training strategies in intact teams: A meta-analysis. *Small Group Research*, 38, p.471.

Salancik, G.R., & Pfeffer, J. (1978). A social information processing approach to job attitudes and job design. *Administrative Science Quarterly*, 23, 224-253.

Song, X. M. & M.E.Parry (1997). A cross-national comparative study of new product development processes: Japan and the United States. *Journal of Marketing,* 64(2), 1–14.

Teasley, R. & R. B. Robinson (2005). Modeling knowledge-based entrepreneurship and innovation in Japanese organizations. *International Journal of Entrepreneurship*, 9, 19-44.

Teasley, R., Kodama, F. and R. Robinson (2009). Do collectivist teams matter? Effects of project group context on interdependence and innovative capabilities. *Journal of International Business Research*, 8, 1, 1-28.

Thompson, J.D. 1967. *Organizations in Action* (New York: McGraw-Hill).

Tushman, M. (1978). Technical communication in research and development laboratories: Impact of project work characteristics. *Academy of Management Journal*, 21, 624–645.

Trott, P. (2008). *Innovation Management and New Product Development*, 4th ed. (London: Prentice Hall).

Wagner, J. (1995). Studies of individualism-collectivism: Effects on cooperation in groups. *Academy of Management Journal*, 42, 127-137.

Weaver, C. (1980). Job satisfaction in the United States in the 1970s. *Journal of Applied Psychology,* 65(3) 364-367.

Wen, J. and S. Kobayashi (2001). Exploring collaborative R&D network: Some new evidence in Japan. *Research Policy*. 30(8), p.1309.

Westney, D. Eleanor and Kiyobori Sakakibara 1985. The role of Japan-based R&D in global technology strategy. Technology in Society &: 315-330.

Whitley, R. and P. Frost (1971). The measurement of performance in research. *Human Relations,* 24: 161-177.

Woodward, J. (1958). Management and Technology (London: Her Majesty's Stationary Office).

Zahra, S. and J. Covin (1995). Contextual influences on the corporate entrepreneurship relationship: A longitudinal analysis. *Journal of Business Venturing*, 10(1), 43-59.

AN EMPIRICAL ANALYSIS OF STUDENTS' DIFFICULTIES ON LEARNING CONCEPTUAL DATA MODELING

I-Lin Huang, Langston University

ABSTRACT

Conceptual data modeling is an error prone process, especially for student database modelers. In order to improve the accuracy of data models, the entity-relationship modeling has been accepted by academics and practitioners as an effective technique to help database modelers to capture, understand, and represent business data requirements. However, the cognitive abilities of database modelers are still the most important determinants for the accuracy of data models.

Empirical studies have showed that the performance of student database modelers is significantly lower than that of expert database modelers. The results are well-expected because student database modelers are obviously inadequate in modeling knowledge of the data modeling technique. However, empirical studies have also shown that the learning process is slow for student database modelers to reach the expert level of reasoning processes and modeling performance. This result poses an unanswered question: why student database modelers cannot have significantly better performance of data modeling once they have learned the modeling knowledge?

After reviewing the literature on conceptual modeling, this research proposes that in addition to modeling knowledge, two cognitive variables, domain knowledge and cognitive fit; also significantly influence the modeling performance of student database modelers. An experiment is then conducted to test the influence of domain knowledge and cognitive fit on the modeling performance of student database modelers. On the basis of the research results, this research suggests that an effective instruction system for training student data modelers needs to consider the influence of domain knowledge and cognitive fit.

INTRODUCTION

Statistics show that database administration is one of five fastest growth areas in the job market for the first decade of the new millennium (Newsweek, 1999, page 44, New York Times, 2001). The growth of the demand for competent database modelers reflects the importance of the quality of database systems in supporting wide-spreading e-businesses and enterprise resource planning systems in current business environments (Antony & Batra, 2002). The importance of the quality of database systems in current business environments has also been demonstrated by the vast expense of businesses in erroneous data due to poorly designed databases. According to an estimation, the erroneous customer data alone cost businesses on a

global level ranging from under $100 billion to over $600 billion, not to mention the erroneous data in other aspects of businesses (Hillard, McClowry, & Na, 2007).

An accurate data model is essential to building a well-functioning database. In developing a database, the data model provides a blueprint and foundation for the structure of the database by showing an abstract representation of the data about entities, their associations and attributes within the intended business (Topi & Ramesh, 2002). If the data model is flawed, the quality of the resulting database will be compromised.

However, conceptual data modeling is an error prone process, especially for student database modelers (Antony & Batra, 2002; Batra, 2005; Batra and Sein; 1994; Sutcliffe and Maiden, 1992). In order to improve the accuracy of data models, the entity-relationship modeling has long been accepted by academics and practitioners as an effective technique to help database modelers to capture, understand, and represent business data requirements (Antony & Batra, 2002; Batra and Davis, 1992; Batra and Sein; 1994). However, the cognitive abilities of database modelers are still the most important determinants for the accuracy of data models. It has been reported that student database modelers literally follow the stated requirements to specify entity-relationship models (Batra & Antony, 1994). As a result, the data relationships that are not expressed obviously in requirement statements become the main source of modeling errors committed by students (Batra and Davis, 1992; Batra and Sein; 1994; Sutcliffe and Maiden, 1992).

The learning process is slow for student database modelers to reach the expert level of reasoning processes and knowledge organizations (Huang, and Burns, 2000; Schenk, Vitalari, and Davis, 1998). Expert database modelers can use data modeling techniques to perform model-based reasoning more effectively. In addition, expert database modelers can reuse rich and well-organized model patterns from their experience (Batra and Davis, 1992; Batra and Sein; 1994; Sutcliffe and Maiden, 1992). As a result, expert data modelers show significantly better performance in data modeling than student data modelers. Therefore, the research question for this paper is: what are the cognitive variables, in addition to modeling knowledge, that make student database modelers difficult to specify accurate data models.

The rest of this paper is organized as follows. First, I review the literature on the important variables of conceptual modeling. On the basis of the reviewed literature, I then propose domain knowledge and cognitive gap as two important variables in determining the performance of conceptual modeling. Next, I specify the design of experiment for this research. Four treatments are designed to represent the four combinations of the two independent variables, domain knowledge and cognitive gap. Next, I analyze the research findings from the experiment; and then discuss the effects of the design and constraints of the research experiment on the research findings. Finally, I make a conclusion in the final section.

LITERATURE REVIEW

The accuracy of conceptual models in general and conceptual data models in particular is determined by the performance of conceptual modelers in understanding and documenting conceptual models. In order to improve the performance of modelers, various modeling techniques have been proposed. Although the contribution of modeling techniques to the

performance of modelers has been well recognized, it is unclear why modeling techniques cannot improve student modelers' performance consistently. In order to understand students' performance in conceptual modeling, the cognitive environment of modelers for understanding and specifying conceptual models has become an important area of research. This research categorizes the literature on the cognitive environment of modelers along two dimensions: knowledge availability and cognitive fit of the modelers.

Knowledge Availability

The availability of domain knowledge and that of modeling knowledge have long been suggested as determining factors for the performance of conceptual modeling (Huang, 2008 & 2011). In this section, I review the influence of modeling knowledge and domain knowledge on the performance of conceptual modeling. On the basis of the review, a research hypothesis is then proposed at the end of this section.

First, modeling knowledge has long been regarded as an important factor to differentiate expert from student modelers. Modeling knowledge can be divided into syntactic and semantic parts (Koubek, et al., 1989). Syntactic knowledge consists of allowable syntax of a specific modeling language. Semantic knowledge, however, consists of modeling principles that are independent of a particular modeling language (Allwood, 1986). Compared to student modelers, expert modelers with richer semantic knowledge can retrieve and apply more relevant modeling principles, make more critical testing of hypotheses, and finally achieve conceptual models with better quality (Allwood, 1986; Koubek, et al., 1989; Schenk, Vitalari, & Davis, 1998; Vitalari & Dickson, 1983). Modeling knowledge can also be divided into declarative and procedural aspects (Vessey & Conger, 1993). The procedural aspect of a modeling technique is more difficult to learn than the declarative aspect. However, the procedural aspect of modeling knowledge is more important in determining the quality of conceptual models (Vessey & Coger, 1993).

On the other hand, Domain knowledge is drawn upon by both expert and student modelers in specifying conceptual models (Sutcliffe & Maiden, 1990; Vessey & Conger, 1993). While understanding problem statements, modelers use domain knowledge to mentally simulate a scenario of the system behavior in order to test the adequacy of the conceptual models, to add assumptions to increase the completeness of the requirements, to test internal and external consistency of the requirements, and to abstract, summarize, select and highlight important information in the problem statements (Guindon, Krasnar, & Curtis, 1987). Without domain knowledge, even expert modelers can only specify high-level conceptual models without details (Adelson & Soloway, 1985). With the availability of domain knowledge, student modelers can reuse the domain knowledge to achieve almost the same level of completeness of conceptual models as expert modelers do (Sutcliffe & Maiden, 1990).

Due to the well-recognition of modeling knowledge as the determining factor for the performance of conceptual modeling, this research treats modeling knowledge as a controlled variable and is focused on the effect of domain knowledge on the performance of conceptual modeling. On the basis of the literature reviewed on domain knowledge, this research suggests a research hypothesis as below:

H 1 Modelers with richer domain knowledge can specify more accurate conceptual models than those with poorer domain knowledge.

Cognitive Fit

Conceptual modeling is a structure-building process that translates the ontologies of problem domains into those of modeling techniques (Huang, 2008 & 2011; Huang & Burns, 2000). The cognitive gap between a problem domain and a modeling technique can be evaluated by the difference of ontologies used by the problem domain and the modeling technique. An ontology is a conceptual system (Guarino & Giaretta, 1995; Regoczei & Plantinga, 1987) that includes two parts: (1) a set of concepts for describing a problem domain such as entities, relationships, data flows, and agents; and (2) a cognitive structure for organizing the concepts such as function orientation, object orientation, data orientation, and control orientation (Marca & McGowan, 1993; Pepper, 1942). The difference in ontologies determines how difficult it is for modelers to model a problem domain by a particular modeling technique (Huang, 2008 & 2011; Huang & Burns, 2000).

In this section, I review the influence of cognitive fit on the performance of conceptual modeling from two perspectives: (1) modeling techniques, and (2) problem domains. A research hypothesis is then proposed at the end of this section.

(1) Modeling techniques

The main purpose of modeling techniques is to provide notations and procedures to help modelers formalize the domain knowledge of problem domains during the process of conceptual modeling (Sutcliffe & Maiden, 1992). Different sets of criteria have been proposed to evaluate the performance of modeling techniques (Davis, 1988; Roman, 1985; Yadav, Bravoco, Chatfield, & Rajkumar, 1988). However, the most important two criteria are accuracy and completeness because they are the major factors determining the success of an information system development project (Standish Group, 1995; Yadav & Chand, 1989). The review in this section is focused on accuracy, and sometimes, completeness as criteria for the performance of conceptual modeling.

The empirical evidence has shown that modeling techniques can improve the performance of modelers. It was found that modelers who specified conceptual models by model-based reasoning based on modeling techniques could produce more complete solutions than those with partial or no model-based reasoning behavior (Sutcliffe & Maiden, 1992).

Although the contribution of modeling techniques to the accuracy of conceptual models is well recognized, it is unclear how modeling techniques influence the accuracy of conceptual models. The failure of identifying the key features of modeling techniques that determine the accuracy of conceptual models can be attributed to three unsettled research findings: (1) no modeling technique has consistently better performance than any other technique; (2) modeling techniques provide significantly better support for expert modelers than for student modelers; and (3) expert modelers tend to use multiple modeling techniques simultaneously to analyze information requirements (Huang, 2008 & 2011; Huang & Burns, 2000). First, there have been

several research studies on comparing the performance of different modeling techniques. However, the results are inconsistent. In comparing the effectiveness of data flow diagrams and IDEF for supporting student modelers in specifying information requirements, it was found that data flow diagrams were easier to learn and to use. However, neither of them (DFDs and IDEFs) produced significantly better specifications (Yadav, Bravoco, Chatfield, & Raikumar, 1988). Since object orientation became a new paradigm for conceptual modeling, there has been a debate on which approach, the object orientation or the functional orientation, is a more "natural" way to specify conceptual models (Firesmith, 1991; Loy, 1990; Shumate, 1991). The reported results on the basis of empirical studies were conflicting. Kim and Lerch (1992) reported that expert modelers with object-oriented techniques spent less time in analyzing problem domains and developed better understanding of the underlying problem structures than expert modelers with function-oriented techniques. However, Vessey and Cogner (1994) found that student modelers were better able to apply the function-oriented techniques than to apply the object-oriented techniques. In addition, significant learning effects only occurred for the functional techniques. In sum, no modeling technique can consistently outperform other techniques.

Second, expert modelers can generate more complete conceptual models by model-based reasoning based on modeling techniques. The constructs provided by modeling techniques can help expert modelers focus on important concepts in problem domains. However, empirical studies showed that student modelers have difficulty in identifying important concepts in requirement statements with modeling techniques (Batra & Davis, 1992; Batra & Sein, 1994; Sutcliffe & Maiden, 1992). Sutcliffe and Maiden (1992) found that student modelers could easily identify system goals and inputs in a requirement statement. But they had poor performance in recognizing system processes, data stores and outputs even though those were explicitly stated in the requirement statement. Batra and Davis (1992) focused on the similarities and differences of database modeling behaviors by entity-relationship diagrams between student and expert modelers. They found that student modelers had similar performance with expert modelers in classifying objects as an entity or an attribute, and in modeling binary relationships. However, student modelers had significantly bigger difficulty in identifying unary relationships and categories. Therefore, the difference in cognitive ability to recognize some concepts and relationships can explain why modeling techniques can improve the performance of expert modelers significantly while provide little help for student modelers. But it is unclear why student modelers have trouble with some concepts and relationships.

Third, even though expert modelers are skilled at modeling techniques, they use multiple modeling techniques, rather than a particular one, in analyzing complex conceptual models (Littman, 1989; Wijers & Heijes, 1990). Littman (1989) conducted several empirical studies to investigate the ways that expert software modelers constructed mental representations of problem domains. He found that expert software modelers used multiple mental representations to model problem domains. Littman reported that expert software modelers identified several modeling techniques that might be appropriate for a problem domain and then selected one that seemed most appropriate. Wijers and Heijes (1990) observed an experiment on constructing a global information model consisting of a functional decomposition, entity-relationship models, and dataflow diagrams. They found that expert modelers had different preferred techniques. In addition, they have strong flexibility in choosing different techniques in analyzing different parts

of information requirements. Therefore, the modeling behaviors of expert modelers seem to imply that the performance of modeling techniques depends on the characteristics of problem domains. However, it is unclear what the characteristics of problem domains determine the performance of modeling techniques.

(2) Problem Domains

The research into the relationships between problem domains and modeling techniques argues that the characteristics of problem domains should be the basis for the selection of modeling techniques for conceptual modeling. Vessey and Galletta (1991) believed that the fit between the mode of information presentation and the task would influence the performance of problem solving or decision making. They therefore conducted an experiment of comparing subjects and performance of problem solving by matching two modes of information presentation, table and graph, with two types of tasks, spatial or symbolic. They concluded that subjects' performance of problem solving was improved by matching the problem representation with the task. In addition, the performance would be improved even further if the subjects' skill could match the problem representation and the task. Vessey and Glass (Fall 1994) extended the above findings and argued that cognitive fit between application types and modeling techniques was important for the effectiveness of conceptual modeling. They suggested that taxonomies of applications and taxonomies of modeling techniques were needed to facilitate matching techniques to application tasks (Vessey & Glass, 1998). To match modeling techniques to application tasks, Sowa and Zachman (1992) provided a framework to categorize modeling techniques on the basis of six dimensions: data, process, network, people, time, and motivation. Opdahl and Sindre (1995) proposed a facet-modeling structure to integrate various modeling techniques. Jackson (November 1994) suggested that future modeling techniques should be more problem-oriented to fit the structures of problem domains rather than solution-oriented.

On the basis of the reviewed literature on modeling techniques and problem domains, this research suggest a research hypothesis concerning cognitive fit as below:

H 2 Modelers using a modeling technique that cognitively fits the text structure of the problem statement can specify more accurate conceptual models than those using modeling techniques that do not cognitively fit the text structure of the problem statement.

EXPERIMENT DESIGN

The purpose of the experiment is to test the influences of cognitive fit and domain knowledge on the performance of student data modelers on the accuracy of data models. The data modeling technique used in this experiment is entity-relationship modeling technique. On the basis of the hypotheses derived in the section of literature review, the hypotheses to be tested in this experiment can be restated more specific as follows:

1. The effect of domain knowledge:
   Student data modelers specify more accurate entity-relationship data models for familiar problem domains than for unfamiliar problem domains.
2. The effect of cognitive fit:
   Student data modelers specify more accurate entity-relationship data models when there is cognitive fit between entity-relationship modeling techniques and the text structures of problem statements than when there is no cognitive fit between entity-relationship modeling techniques and the text structures of the problem statements.

Subject

Subjects were 24 undergraduate students who were taking the course of Database Systems at a regional university in the United States. To motivate the subjects to perform to the best of their abilities, they earned different bonus points for the course on the basis of their performance in the experiment. The students had taken zero to five computer-related courses before the experiment. They had zero to five years of work experience on computer-related jobs. However, they did not have experience of using entity-relationship diagrams to specify database requirements. Therefore, they were regarded as student modelers in this experiment.

Treatment

Four problem statements were assigned to each student in random sequence. Each problem statement corresponded to one of four treatments: familiar domain and high ER-oriented text structure (high domain knowledge and high cognitive fit), familiar domain and low ER-oriented text structure (high domain knowledge and low cognitive fit), unfamiliar domain and high ER-oriented text structure (low domain knowledge and high cognitive fit), and unfamiliar domain and low ER-oriented text structure (low domain knowledge and low cognitive fit). The important features of the four problem statements as follows:

First, a problem statement about video rental system described in a way that focused on data relationships as the major means of text connection represented the treatment of familiar domain and high ER-oriented text structure.

Second, a problem statement about course registration system described in a way that focused on processes as the major means of text connection represented the treatment of familiar domain and low ER-oriented text structure.

Third, a problem statement about project management system described in a way that focused on data relationships as the major means of text connection represented the treatment of unfamiliar domain and high ER-oriented text structure.

Fourth and finally, a problem statement about production scheduling system described in a way that focused on processes as the major means of text connection represented the treatment of unfamiliar domain and low ER-oriented text structure.

Data Modeling Technique

In this experiment, the students were asked to use the entity-relationship diagrams as the technique to specify database requirements. Therefore, the problem statements with a high ER-oriented text structure had better cognitive fit than those with a low ER-oriented text structure.

Performance Measurement

In this experiment, rate of accuracy was used as the performance measurement for the entity-relationship diagrams drawn by the students. For each entity-relationship, the number of correct entities and correct relationships were counted. Then the rate of accuracy for each entity-relationship were calculated by dividing the number of correct constructs (including entities and relationships) in the entity-relationship diagram by the total number of correct constructs for the problem statement.

Experimental Procedure

Prior to the experiment, the students accepted training for entity-relationship modeling for nine hours in three weeks, three hours for each week. In the first week the students accepted a lecture about the concepts and procedure for entity-relationship modeling, and in the next two weeks the students practiced on entity-relationship modeling for six questions. The students were also asked to do a homework assignment involving one modeling question one week before participating in the experiment.

A pilot test was conducted before the experiment. A professor and an undergraduate student in MIS were asked to work through the experimental materials to identify any deficiencies in the experimental materials.

At the beginning of the experiment, the students were asked to read and sign a consent form. The experimenter also mentioned the bonus points that students could get by participating in the experiment. During the experiment, the students developed an entity-relationship diagram for each of four problem statements in a random sequence. The students were allowed to do each question only for 20 minutes. If students finished a modeling question earlier, they were not allowed to move on to the next question until the end of the twenty-minute session.

After finishing the four modeling questions, the students were asked to fill out a questionnaire about their basic information, what the most difficult and easiest problems were in the test and why according to their impressions.

Grading Procedure

Two graders were trained to grade independently each of the entity-relationship diagrams in this experiment. Neither of the two graders had any background on entity-relationship modeling before. The graders accepted training about the concepts of entity-relationship

diagrams for thirty minutes. Then they practiced grading one entity-relationship diagram for each of the four modeling problems before they formally graded the test.

After both graders finished their grading, a Pearson Correlation Coefficient was calculated to measure the inter-rater reliability. The value of the correlation was 0.82571, which reflected a significant correlation of the grading results between the two graders. The significance of the correlation also showed that the grading procedure was reliable. Therefore, the grading done by one of the two graders was selected for the subsequent data analysis. The grading that was finally selected was from the grader with more experience in grading.

EXPERIMENT FINDINGS

Table 1 shows the basic descriptive information about this experiment. The mean rate of accuracy (ROA) reveals the performance of the students for the four test problems. The problems with performance from the best to the worst are: video rental problem (high domain knowledge, high cognitive fit), course registration problem (high domain knowledge, low cognitive fit), project management problem (low domain knowledge, high cognitive fit), and production management (low domain knowledge, low cognitive fit). One-way ANOVA also shows that the effects of domain knowledge and cognitive fit are significant. In addition, the LSD test for mean comparison shows that the performances for the four problems are significantly different.

Table 1: Descriptive statistics for rate of accuracy (ROA)

Problem	Sample Size	Mean ROA	Max ROA	Min ROA	STD
Video Rental	24	0.625	1.000	0.153	0.202
Course Registration	24	0.456	0.688	0.188	0.120
Project Management	24	0.356	0.700	0.100	0.160
Production Management	24	0.248	0.421	0.157	0.074

The result is consistent with expectation: both domain knowledge and cognitive fit have significantly positive effect on students' performance. In addition, this research shows that domain knowledge has stronger effect than cognitive fit on the accuracy of the conceptual models. As a result, the sequence of the performances of the students in the four problems is like that in Table 1.

On the other hand, the high values of the standard deviation (STD) reflect that the students' performances are very different. Some students may get perfect scores for some problems while some get very low scores. The factor of individual differences has strong effect on the dependent variable, the rate of accuracy.

The result from two-way ANOVA with interaction is shown in table 2. The result reveals that the interaction between domain knowledge and cognitive fit is not significant. Therefore, we can do two-way ANOVA without interaction as shown in Table 3. Due to the insignificance

of interaction, two-way ANOVA without interaction will show more significant main effects of domain knowledge and cognitive fit than two-way ANOVA with interaction. An analysis of the two main effects is as follows:

Table 2: Two-way ANOVA with interaction	
Effect	p-value
Domain Knowledge	< 0.0001
Cognitive Fit	0.0119
Interaction	0.32

Table 3: Two-way ANOVA without interaction	
Effect	p-value
Domain Knowledge	< 0.0001
Cognitive Fit	< 0.0001

The Effect of Domain Knowledge.

From the p-values in Table 2 and Table 3, the effect of domain knowledge on the rate of accuracy of the conceptual models is significant. This result supports the research hypothesis one in this research. In addition, this result also reaffirms the well-recognized effect of domain knowledge on the accuracy of requirement specification. According to the cognitive research in conceptual modeling, domain knowledge is very important for perform mental simulation of a problem statement. Without domain knowledge, even expert modelers can only specify high-level conceptual models without details (Adelson & Soloway, 1985). With the availability of domain knowledge, student modelers can reuse the domain knowledge to achieve almost the same level of completeness of conceptual models as expert modelers do (Sutcliffe & Maiden, 1990).

The Effect of Cognitive Fit.

The p-values in Table 2 and Table 3 show that the effect of cognitive fit is very significant. This result not only supports the second research hypothesis in this research, but also answers two of the three important unsolved problems on the performance of modeling techniques in the section of literature review. First, the effect of cognitive fit explains that no modeling technique can consistently outperform the other modeling techniques because the performance of a modeling technique is determined by how well it match to the text structure of the intended problem statement. Second, the effect of cognitive fit also explains that expert modelers use multiple modeling techniques simultaneously during modeling because different techniques are matched to the text structures of different parts of the problem statement.

DISCUSSION

The students participating in this experiment could be categorized into student modelers because they had limited, if any, experience in entity-relationship modeling before attending the course of Database Systems. However, on the basis of the values of standard deviation for this experiment, we can find out that the students had developed significantly different levels of skill to use entity-relationship diagrams to specify database requirements. The individual differences in the modeling performance in this experiment reaffirm that human cognitive ability is the most important factor for determining the performance of conceptual modeling.

This experiment has shown that both domain knowledge and cognitive fit have significant effect on the students' performance in conceptual models. In this experiment we used two problems to represent familiar problem domains: the video rental system and the course registration. I assumed that students had rich domain knowledge about these two systems. On the other hand, I used the production scheduling system and the project management system to represent unfamiliar problem domain. I assumed that the students did not have strong domain knowledge about these two problems. In the questionnaire after the experiment, students showed the same feeling of familiarity for the four problems as described above. The video rental system was the easiest problem for them. Among 24 subjects, 19 said the video rental system is the easiest problem, and the rest six said the course registration system is the easiest one. Most of them felt that the reasons for the easiness of the video rental system are because of the familiarity of the problem domain (domain knowledge) or the simplicity of problem statement (cognitive fit). On the other hand, 22 subjects said that the production scheduling problem is the most difficult problem, and the rest two voted for the project management problem. Most of the students felt that the production schedule problem was the most difficult one because of their lacking of experience on this system (domain knowledge) or the complexity of the problem statement (cognitive fit).

CONCLUSION

The research results revealed the importance of domain knowledge and cognitive fit for conceptual modeling. Without adequate domain knowledge, modelers cannot perform well in conceptual modeling no matter how good the fit is between problem domains and modeling techniques. On the other hand, a cognitive unfit between a problem statement and a modeling technique will definitely reduce the rate of accuracy in the final conceptual models significantly even with strong domain knowledge support.

There are two important implications identified by this research study: first, in comparing different empirical studies, it was confusing that the performance of student modelers varies dramatically form one study to another. On the basis of this research, we can understand that the variability is caused by the different levels of cognitive fit and domain knowledge in the

research settings of different research studies. Second, an effective design of an instruction system for learning conceptual modeling should not only focus on the design of learning modeling knowledge, but also on the design of a learning environment with appropriate cognitive fit and domain knowledge support.

REFERENCES

Adelson, B., & Soloway, E. (1985). The role of domain experience in software design. *IEEE Transactions On Software Engineering*, 11 (11), 1351-1360.

Allwood, C. M. (1986). Novices on the computer: a review of the literature. *International Journal of Man-Machine Studies*, 25, 633-658.

Antony, S. R. & Batra, D. (2002). CODASYS: a consulting tool for novice database modelers. *ACM SIGMIS Database,* 33(3), 54-68.

Batra, D. (2005). Conceptual Data Modeling Patterns: Representation and Validation. *Journal of Database Management*. 16(2), 84-106.

Batra, D. & and Antony, S. R. (1994). Novice errors in conceptual database design. *European Journal of Information Systems*, 3, 57-69.

Batra, D., & Davis, J. G. (1992). Conceptual data modeling in database design: similarities and differences between expert and novice modelers. *International Journal of Man-Machine Studies, 37,* 83-101.

Batra, D. & Sein, M.K. (1994). Improving Conceptual Database Design Through Feedback. *International Journal of Human-Computer Studies*. 40(4), 653-676.

Davis, A. M. (1988). A comparison of techniques for the specification of external system behavior. *Communications of The ACM, 31* (9), 1098-1115.

Firesmith, D. (1991). Structured analysis and object-oriented development are not compatible. *Ada Letters, XI* (9), 56-66.

Guarino, N., & Giaretta, P. (1995). Ontologies and knowledge bases towards a terminological clarification. In *Proceedings of the Second Conference on Building and Sharing of Very Large-Scale Knowledge Base* (pp. 25-32). Amsterdam: IOS Press.

Guindon, R., Krasner, H., & Curtis, B. (1987). Cognitive process in software design: activities in early, upstream design. In H. J. Bullinger & B. Shackel (Eds), *Human-computer Interaction, INTERACT'97* (pp. 383-388). Amsterdam: North-Holland.

Hillard, R., McClowry, S. & Na, L. (2007). *The Economic Value ofInformation*. *Access from* http://mike2.openmethodology.org/index.php/Economic_Value_of_Information

Huang, I (2011). Analyze the cognitive process of information requirement analysis. *Academy of Information and Management Sciences Journal*, 14(1), 53-68.

Huang, I (2008). A cognitive explanation of the correctness of information requirement specifications. *Academy of Information and Management Sciences Journal*, 11(2), 1-18.

Huang, I., & Burns, J. R. (2000). A cognitive comparison of modeling behaviors between novice and expert information analysts. *Proceedings of AMCIS Conference*, 1316-1322.

Jackson, M. (1994, November). Problems, methods and specialization. *IEEE Software*, 57-62.

Kim J., & Lerch, F. J. (1992). Towards a model of cognitive process in logical design: comparing object-oriented and traditional functional decomposition software methodologies. In *Proceedings of CHI'92* (pp. 489-498). New York: ACM Press.

Koubek, R. J., Salvendy, G., Dunsmor, H. E., & Lebold, W. K. (1989). Cognitive issues in the process of software development: review and reappraisal. *International Journal of Man-Machine Studies, 30*, 171-191.

Littman, D. (1989). Constructing expert systems as building mental models. In K. Morik (Ed.), *Knowledge Representation and Organization in Machine Learning* (pp. 88-106). Berlin: Springer-Verlag.

Loy, P. H. (1990). A comparison of object-oriented and structured development methods. *Software Engineering Notes, 15* (1), 44-48.

Mainden, N. A., & Sutcliffe, A. G. (1992). Exploiting reusable specifications through analogy. *Communication of The ACM, 35* (4), 55-64.

Marca, D. A., & McGowan, C. L. (1993). Specification approaches express different world hypotheses. In *Proceedings of the Seventh International Workshop on Software Specification and Design* (pp. 214-223). Los Alamitos, CA: IEEE Computer Society Press.

New York Times (2001). Job Forecast: Internet's Still Hot, January 30, 2001.

Newsweek (1999). Your Next Job. February 1, 1999, pp. 44-46

Opdahl, A. L., & Sindre, G. (1995). Facet models for problem analysis. *Advanced Information System Engineering*, 54-67.

Pepper, S. C. (1942). *World Hypotheses: A Study in Evidence*. Berkeley, CA: University of California Press.

Regoczei, S., & Plantinga, E. P. O. (1987). Creating the domain of discourse: ontology and inventory. *International Journal of Man-Machine Studies, 27*, 235-250.

Roman, G. (1985, April). A taxonomy of current issues in requirements engineering. *IEEE Computer*, 14-22.

Schenk, K. D., Vitalari, N. P., & Davis, K. S. (1998). Differences between novice and expert systems analysts: what do we know and what do we do? *Journal of Management Information Systems, 15* (1), 9-50.

Shumate, K. (1991). Structured analysis and object-oriented design are compatible. *Ada Letters, XI* (4), 78-90.

Sowa, J. F., & Zachman, J. A. (1992). Extending and formalizing the framework for information systems architecture. *IBM Systems Journal, 31* (3), 590-616.

Standish Group (1995). The Standish Group Report: CHAOS, 1995. http://www.scs.carleton.ca/~beau/PM/Standish-Report.html

Sutcliffe, A., & Maiden, N. (1992). Analysing the novice analyst: cognitive model in software engineering. *International Journal of Man-Machine Studies, 36*, 719-740.

Topi H. & Ramesh V. (2002). : Human Factors Research on Data Modeling: A Review of Prior Research, an Extended Framework and Future Research Directions. *Journal of Database Management, 13(*2), 3-19.

Vessey, I., & Conger, S. A. (1993). Learning to specify information requirements: the relationship between application and methodology. *Journal of Management Information Systems, 10* (2), 177-201.

Vessey, I., & Galletta, D. (1991). Cognitive fit: an empirical study of information acquisition. *Information Systems Research, 2* (1), 63-84.

Vitalari, N. P., & Dickson, G. W. (1983). Problem solving for effective system analysis: an experimental exploration. *Communications of the ACM, 26* (11), 948-956.

Wijers, G. M., & Heijes, H. (1990). Automated support of the modeling process: a view based on experiments with expert information engineers. *Lecture Notes in Computer Science* (pp. 88-106). Berlin: Spring-Verlag.

Yadav, S. B., Bravoco, R. R., Chatfield, A. T., & Rajkumar, T. M. (1988). Comparison of analysis techniques for information requirement determination. *Communication of the ACM, 31* (9), 1090-1097.

Yadav, S. B., & Chand, D. R. (1989). An expert modeling support system for modeling an object system to specify its information requirements. *Decision Support Systems, 5*, 29-45.

INFORMATION TECHNOLOGY POLICIES AND PROCEDURES AGAINST UNSTRUCTURED DATA: A PHENOMENOLOGICAL STUDY OF INFORMATION TECHNOLOGY PROFESSIONALS

Vesal Tirgari, University of Phoenix

ABSTRACT

The phenomenological study explored the lived experiences and perceptions of a purposive sample of 20 IT professionals (managers, engineers, administrators, and analysts) in the state of Virginia, Texas, and Washington DC. The focus of this research study was to learn the perceptions of IT professionals who are or once were in a decision-making position concerning the contents of network storage. The study's interest was in patterns of use for network storage in organizational settings. The specific problem was the underdeveloped IT policies and procedures that can lead to the presence of unstructured data that does not represent a significant value to an organization. The focus of this research study was to seek from these IT professionals their perceptions of what the connection is between the IT policies and procedures against the storage of unstructured data. The significance of the phenomenological study to leadership was to provide leaders with the opportunity to facilitate an organizational environment, which the business corresponds with the direction of IT and the leaders are committed to make good use of technology to support the organizations needs. The findings are aimed to provide IT leaders and IT professional's methods on how to better control unstructured data, build policies and procedures, educate end users, and guide better data management.

INTRODUCTION

Decades ago information technology (IT) was comprised of "centralized mainframes that were connected to dedicated disks and tape drives" (Castagna, 2008, p. 6). IT professionals of various organizations are now using servers that have the capabilities of quad core processors, high-speed memory, high capacity drives, and virtualization (Castagna, 2008). Organizations are becoming more complex with the introduction of new technology requiring strict security guidelines to be enforced and documented (Whitten, 2008). Leaders of organizations establish IT policies against improper use of technology and use of the network. The lack of developed IT policies and procedures pertaining to the storage of business related and personal unstructured data is a problem because unstructured data takes up valuable business resources (Lazarides, 2007). Lazarides (2007) noted that IT auditing is obligatory for organizations and so are best practice methods, and protocols, which are being implemented to insure internal control and accountability. The phenomenological study aims to provide recommendations to IT leaders and

IT professionals on how to better control unstructured data, build policies and procedures, educate end users, and guide better data management.

Purpose of the Study

The purpose of this qualitative phenomenological study was to explore from a purposive sample of 20 IT professionals (managers, engineers, administrators, and analysts). The participants were all from Virginia, Texas and Washington DC. Additionally, the study was to learn the perceptions of IT professionals on how and why data storage decisions were made by exploring contents of network storage and IT policies against unstructured data on a corporate wide network. For the purpose of this study the term IT policies and procedures is defined as a set of organizational wide protocols that is documented and followed to ensure integrity, security, and availability of computer systems. Creswell suggested that new knowledge might be gained from insights and lived experiences of 5 to 20 individuals (Creswell, 2007). A total of 20 participants were interviewed for this qualitative phenomenological study. The phenomenological research allowed for the lived experiences of the participants involved or, who were once involved with an issue relating to data storage to be captured and be used for further exploration (Moustakas, 1994).

Significance of Study

This study is important because every year organizations spend a large amount of their IT budget on storage in order to meet the high demand of data growth (Swartz, 2007). There are no previously known research studies that have the same or similar purpose of this research study. One of the defining attributes of this research study is the unknown research variables. A qualitative research study best met the needs of this study because limited research has been conducted on this topic. The study aims to provide recommendations to IT leaders and IT professionals on how to better control unstructured data, build policies and procedures, educate end users, and guide better data management.

According to Swartz (2007), "when asked what factors are driving the need for archiving in their organization, 70% of respondents said disaster recovery/business continuity, 62% cited data growth, and 58% answered regulatory compliance" (p. 14). According to Swartz (2007), "More than 18% more respondents in 2006 than in 2005 said they could recoup over half of their most expensive primary disk space by removing unwanted data" (p. 14). Based on the statistics discussed by Swartz (2007) the study may assist IT professionals in better administrating data storage requirements within organizations. The study may contribute to better understanding the perceptions of IT professionals and what the connection is between IT policies and procedures against the storage of unstructured data. Expectations of the phenomenological study included improving the impact on overall business resources and practices for data storage. Intentions were that current and future studies could build off the phenomenological study and provide a better means of data storage for organizations to meet business needs.

The biggest management challenge is integrating information systems across the globe with the expansion of businesses, off shoring and globalization (Byrd, Lewis & Bradley, 2006).

Managing technology in a manner suitable for business is imperative with the ever-growing need for information systems (Byrd, Lewis & Bradley, 2006). The significance of the phenomenological study to leadership was to provide leaders with the opportunity to facilitate an organizational environment where the business corresponds with the direction of IT and the leaders are committed to make good use of technology to support the organizations goals, vision and mission (Booth & Philip, 2005). The expectations of the study included assisting IT leaders in developing IT policies and procedures that meet the needs of various organizations. The study may improve the development of IT leadership strategies and a basis for best practice methods for data storage. Leaders may find methods to provide the best possible technology solution to organizations and/or to improve the fiduciary agreement between organizations and IT leaders on expectations. With the demand for the best possible business value and investments IT leaders and professionals have a responsibility to ensure that the technology is being properly implemented (Hoving, 2007).

LITERATURE REVIEW

The rapid transformation of tape technology to disk technology has provided more storage capabilities for organizations. The competition of hard drives was rapidly increasing, and access to data was becoming faster. The Hard drive capacity was growing rapidly allowing for more data storage (Hellman, Yardy & Abbott, 2003). New methods of storage and technologies allowed for organizations to archive and backup data for longer periods of time.

Data such as memos and presentation files are approaching 100% annual growth (Maby, 2004). Research shows after three days the possibility data will not be accessed again by individuals is 50% (Maby, 2004). In addition, organizations started to see a growth in data and limited space and high dollar amount to upgrade or increase storage capacity (Maby, 2004). Growth in data, limited space and high dollar amounts raise the question of whether or not future technologies will resolve the problem of large amount of employees saving personal data on the corporate network storage system.

Large organizations are in the middle of upgrading their storage environment to accommodate the doubling of data growth every year (Nujeerallee & Anidi, 2002). Leaders who are able to learn the technology, transfer the knowledge to workers, and enforce IT policies against the improper use of the technology is very important in the successful implementation of current state and future implementation of storage technology. IT leadership has been faced with a huge challenge, but this is just the beginning of storage technology and management challenges (Hoving, 2007).

The implementation of new storage technologies has allowed for faster data retrieval, and easier data access has brought new elements of concern to data storage. Determining the data value and storage performance assists in storage capacity and provides benefits to the organization. Some of the benefits include accommodation of data growth, recovery, improved storage management, and a lower cost of gigabytes (Maby, 2004). Data growth has been tremendous over the years with the development of new storage technologies. Knowing the type of data on the network is of concern. Limiting, and recognizing unstructured data is important. The classification of data on the network and finding cheaper alternative for the data can be a

cost saving initiative. With strategic storage planning, archival data should not be piled up erratically (Maby, 2004).

Leaders with the ability to manage the technology, and provide value to the business with the implementation of technology are very important. Leaders with the ability to transfer knowledge, and manage storage technology are equally as important, in the success of providing valuable technology, managing the resources of a IT department and building an organizational culture that is efficient (Hoving, 2007). IT leaders will only build credibility if they only choose and implement the best possible IT technologies and effectively manage a variety of resource properly (Hoving, 2007).

RESEARCH METHODOLOGY

A qualitative research study best met the needs of this study because limited research has been conducted on this topic. Creswell (2007) suggested that qualitative research is best for research problems where little is known about the variables of the study. The research was concerned with observations, interviews, and phenomenology of the IT professionals. The qualitative method appropriate for this study was the phenomenological method because the research was concerned with the lived experiences of professionals in the IT field, their shared experiences, commonalities, and shared meanings (Simon, 2006). For the purpose of this study the research study focused on IT professionals (managers, engineers, administrators, and analysts) concerning their views on IT policies and procedures against unstructured data on the corporate storage networks. Every IT professional has a personal experience to share which can be collected at the same time staying detached (Simon, 2006). Listed are five reasons why a qualitative phenomenological method was appropriate over a quantitative study.

1. The research study has a small number of participants.
2. The research study has a broad purpose.
3. The research study does not make good use of a predetermined instrument.
4. Little is known about the variables of the research study.
5. The data that will be collected is going to be in forms of text and speech (Simon, 2006).

The study included field notes and observation during the interview process of the participants of the study. The primary instruments used in this study included personal face-to-face interviews and telephone interviews. The qualitative phenomenological study used the *NVivo 7.0* qualitative software tool for explicitation of the survey data and discussions by coding and placing the words and phrases into themes. The interview consisted of 16 questions. The questions focused on data storage practices and policies and procedures. In addition, several demographic questions were asked. Appendix A lists the interview and demographic questions that were asked of the participants.

Modification of the van Kaam (1966) approach by Moustakas (1994) included study participants to share personal experiences, documentation of statement and meanings, and description of the essences of lived experiences (Creswell, 2007). The phenomenological study assisted in understanding the experiences of the participants. The phenomenon being studied was

the shared experience of IT professionals (managers, engineers, administrators, and analysts) concerning their views on IT policies and procedures against unstructured data on the corporate storage networks. The use of the qualitative study with a phenomenological design will fully assist in understanding the storage issues in the field of IT. The qualitative study will assist in better understanding the problem and assist in resolving the issues of unstructured data and underdeveloped IT policies and procedures.

Population

The targeted participants were managers, engineers, administrators and analysts in the IT field and currently work within their respected organizations' IT departments. The target population in this study was the IT managers, engineers, administrators, and analysts, which have common defining characteristics that can be identified for the purpose of the study (Creswell, 2007). The criteria for the participants included: The participants of the study will be managers, engineers, administrators, or analysts. A second criterion was the participants in the study had to be at least 18 years of age. The next criterion was for those in leadership positions will have worked in that position for at least 2 years. The fourth criterion was the participants will possess at least a bachelor's degree or certificates in the field of IT. The fifth criterion was the participants will be diverse in ethnic background. The last criterion was the participants will work in Virginia, Texas or Washington DC. Table one list the criteria for the identification of experts from IT professionals to managers (see Table 1). The IT population was asked to participate in the research voluntarily who meet the identified characteristics.

Table 1: Criteria for the Identification of Experts from IT Professionals/Managers
1. The participants of the study were managers, engineers, administrators, and analyst.
2. The participants of the study were at least 18 years of age.
3. Those in leadership positions had worked in that position for at least 2 years.
4. The participants possessed at least a bachelor's degree or certificates in the field of IT.
5. The participants were all diverse in ethnic background.
6. The participants worked in Virginia, Texas, or Washington DC.

Sampling Frame

The qualitative research design was chosen for the purpose of this study to understand the underdeveloped IT policies and unstructured data that reside on the corporate storage environment. Creswell (2007) suggested that qualitative research is best when the researcher is unaware of the variables involved and the literature available does not provide enough information about the study. Thus, the researcher needs to acquire, from participants, through exploration of the problem area. The selected sampling frames that were used for this research study included purposive and snowball sampling techniques. Purposive sampling is a type of sampling, which the researcher uses their own judgment in selecting their subjects based on the criteria of the study (Oxford University Press, 2007). For the purpose of this study a purposive

sample of IT professionals (managers, engineers, administrators, and analysts) were selected that met the criteria listed in (Table 1). The purposive sample was designed to be sufficient in sample size and well-rounded in IT positions to grasp an in depth experience of professionals in the field of IT. The characteristics of the sample are manager, engineer, administrator, or analyst at least 18 years of age. Those in leadership positions will have worked in that position for at least 2 years. The sample must possess at least a bachelor's degree or certificates in the field of IT, diverse in ethnic background, and work in the state of Virginia, Texas and Washington DC.

The initial sample met the criteria and chose to participate in the study. The snowball sampling technique allows for the sharing of potential participants from current participants with the researcher; a sampling technique which additional subjects are referred by the initial subjects (Oxford University Press, 2006). The names and other contact information of potential participants were sought and shared that have met the criteria set forth in Table 1 to participate in this study. The sample of the study was limited to 20 individuals.

The research study provided 20 participants consisting of IT professionals (managers, engineers, administrators, and analysts). Creswell (1998) suggested that interviews take place with up to 10 people in a phenomenological study. The interviews were semi structured and audio taped. The researcher took field notes and observed the participants of the study during the interview process. During the data collection process, three steps were involved according to Moustakas (1994). These steps included creating an *epoche* process and atmosphere for interviewing, bracketing questions, and considering open-ended questions (p. 181).

Data Collection

The data collection for the phenomenological study requires that the researcher follow steps to control the collection of data. A few strict guidelines are to be followed when collecting data in a qualitative study (Simon, 2006). The guidelines include the "exhaustion of resources," the "emergence of regularities," and "overextension" (Simon, 2006, p. 168). The data collection required a systematic process which is entailed in *appendix B* (see Appendix B).
For the purpose of this study, all three of the processes for data collection were considered. The three steps according to Moustakas (1994) include:

1. Engage in Epoche process as a way of creating an atmosphere and rapport for conducting the interview (p. 181).
2. Bracket the question (p. 181).
3. Conduct the qualitative research interview to obtain description of the experience (p. 181). Three steps considered for interviewing are informal interviewing, open-ended questions, and topical guided interviewing.

The approaches that were used in collecting data for the phenomenological study included long interviews where data is collected through the use of audio recording which were then later transcribed for validity. The interview process included an informal, interactive process with open-ended questions (Moustakas, 1994). During the interview process the participants were observed and notes were taken in order to better understand the particular

awareness and impact of the participant, and describe the full experience in the study (Moustakas, 1994). Creswell (2007) suggested data collection techniques such as observations, interviews, documents and audiovisual material. The interviews were recorded using a digital audio recorder, which were played back during the analysis step to transcribe to text.

Validation and Reliability

"Validity and reliability must be addressed in a qualitative study. The qualitative study does not have one best method in validating a study. A qualitative studies accuracy, dependability, and credibility of information depend on it (Simon, 2006). Truth value is important in the accurate description of lived experiences by the participants (Polifroni & Welch, 1999). Polifroni and Welch (1999) defined "Truth value in a qualitative study is found in the accurate description of human experiences as they are lived and perceived by participants in the study" (p. 325). An example of truth value as described by Moustakas (1994) described Humphrey's study where Humphrey interviewed 14 co researchers and sent them copies of his synthesis. Humphrey requested that each of his participants examine the synthesis and out of the 14 participants, eight stated that it was an accurate synthesis. This sort of validity was carried out with each of the research participants. A copy of the interview synthesis, requesting that each participant of the study, examine the transcription for accuracy, was sent out to all participants. Each participant verifying the content of the transcription was required to sign a form, validating its content, before the data analysis process will begin.

Pilot testing of the Interview Protocol, (see Appendix A) with a select group of IT professionals, was conducted, prior to including the questions in the participant interviews. Pilot study participants were asked three additional questions to obtain information about additions, modifications, enhancements, or deletions to the existing Interview Protocol. Permission to use the validation questions is included in Appendix F from Dr. Steven Johnson. Verbal feedback from the pilot participants provided insight into potential issues, such as readability and comprehension of the questions. The pilot testing process is intended to serve as the main source for validating the instrument being used.

Research bracketing was used in the validation of the study to understand and bring into perspective the phenomenon under study. During the analysis phase of the study bracketing was carried out by searching the transcription for the researchers own relationship with the phenomenon under study (Polifroni & Welch, 1999). The importance in bracketing is to return to the transcribed passages that stand out as significant to the study (Polifroni & Welch, 1999). During the bracketing the researcher must take notes on what the emotional experience is, while reading over the transcribed passages and taking note of it (Polifroni & Welch, 1999). By taking notes on personal experiences and themes that have been developed, bracketing allows the phenomenological study to take into account any influence on the decision to carry out the study (Polifroni & Welch, 1999).

Research bracketing was used to understand, in terms of perspectives the phenomenon under study. The bracketing process is an exercise the researcher forgoes to identify assumptions (Neuman, 2005). For the purpose of the phenomenological study bracketing will place brackets around the focus of the study and everything else will be set aside so that everything is solely

based on the topics and questions (Moustakas, 1994). Next the horizonalizing of every statement as having equal value is taken into consideration (Moustakas, 1994). The next step requires that each topic that is irrelevant to the topic, repetitive or overlapping is deleted only leaving horizons (Moustakas, 1994). Next, the clustering of the horizons into themes takes place and the horizons are organized into themes that provide a "textural description of the phenomenon" (Moustakas, 1994, p. 97).

The validity of the data lies in thus richness of the discussion during the interviews with the participants of the study. Three methods to addressing the validity and reliability of qualitative studies include triangulation, feedback, and unique interpretation of events (Simon, 2006). The audio recordings during the interview process will help assist in minimizing errors and contribute to the truth. All interviews were recorded using a digital video recorder and labeled with the assigned interviewer code such as IT01or IT01-B if more than one interview is conducted on the same day. In addition, to carrying out audio recordings participants of the study were provided with a copy of the transcribed interview to verify content which validated their reflected perspectives.

Validity of a study includes internal validity, external validity, and reliability. The validity and reliability of the study is very important in a qualitative study (Simon, 2006). The internal validity of a study is the control of the extraneous variables by the researcher (Simon, 2006). The external validity of a study is the findings of the study that are relevant to the participants and settings beyond the study (Simon, 2006). "The accuracy, dependability, and credibility of the information depend on it" (Simon, 2006, p. 39). There various methods of addressing validity and reliability in a study including triangulation, receiving feedback, and forming interpretation of events in study (Simon, 2006). In the case of the phenomenological study, validity and reliability of the study were performed using audio recordings, which were then transcribed and shared with the participants for verification. The next step included bracketing to set aside any assumptions. Triangulation requires that the researcher confirm evidence, types of data and data collection methods, in the descriptions of a qualitative study (Creswell, 2007). For the purpose of this phenomenological study, triangulation included the researcher's use of multiple methods of data collection; which were interviews, field notes, and confirmation of transcriptions.

EXPLICITATION OF THE SURVEY DATA

The findings of the study were significant in the themes that emerged during data analysis. The data analysis of the phenomenological data resulted in 16 major themes describing the essence of IT professionals from Virginia, Texas, and Washington DC. The perceptions of the IT professionals assisted in seeking to learn their perceptions on how and why data storage decisions are made by exploring contents of network storage and IT policies against unstructured data. The study interview process consisted of in-depth questions intended to guide the interview process and to create a discussion between the participants and the researcher.

The major themes and composite descriptions section of the study will, in detail, identify the 16 major themes (Table 2): strategies to manage data, policies and procedures needed to control unstructured data, new employees orientation, type of IT administration to monitor and

control growth of data, types of security concerns with poor data management, organizational data theft or loss, concerns with data management in IT field, capacity of data storage environment, type of storage technology for primary data, refresher courses for employees, time spent administering data content and management, percentage of unstructured data for data center storage, available data investigation content management programs, data storage technology, data backup techniques, and types of professional development training.

Table 2: Major Themes
1. Strategies to manage data
2. Policies and procedures needed to control unstructured data
3. New employee's orientation
4. Type of IT administration to monitor and control growth of data
5. Types of security concerns with poor data management
6. Organizational data theft or loss
7. Concerns with data management in IT field
8. Capacity of data storage environment
9. Type of storage technology for primary data
10. Refresher courses for employees
11. Time spent administering data content and management
12. Percentage of unstructured data for data center storage
13. Available data investigation content management programs
14. Data storage technology
15. Data backup techniques
16. Types of professional development training

MAJOR THEMES AND COMPOSITE DESCRIPTIONS

The composite description summarizes the meaning of each major theme developed during the explicitation of the survey data. The composite description expands on the data clustering and thematizing section. The composite description provides leaders with more affective methods to handling and reducing unstructured data on the corporate network storage enviornment. The composite description of the major themes also address the utilization of other IT areas that are directly affected by the storage of unstructured data.

Theme1 - Strategies to Manage Data

The participants of the study shared their strategies used to manage data in their data centers. The major theme revealed that many strategies to manage data exist. Many of the strategies will depend on the level and position of the IT professional. From the developed theme it is important that IT professionals do not save anything on the network that does not pertain to work. Separate environments for production and testing are important when developing services.

The task of removing old data from network storage is important in managing data. Configuring storage so that network speed and bandwidth are not affected is critical in the management of data. Strategies include making sure email is archived, data warehouses are managed, proper backup strategies are followed, and increasing storage capacity when needed.

Theme2 - Policies and procedures needed to control unstructured data

The results of the study revealed that policies and procedures are beneficial and critical in controlling unstructured data. The method in which policies and procedures are enforced include making sure end users are educated in the policies and procedures of an organization. Policies and procedures to purge old and unwanted data to another media type are important. Recommendations for policies and procedures include tougher policies and procedures, and stating the repercussions of saving personal data on network storage are important. Policies and procedures on the retention of data on primary storage are very important. Enforcing policies where end users are backing up their data on a regular basis onto external drives needs to be documented.

Theme3 - New employee orientation

The results of the study showed a need for educating new employees on IT policies and procedures. The need for employee orientation is critical in the managing of technology to meet business needs. Employee orientation will allow the education of policies and procedures to be established with new employees coming into the organization. Reading and adhering to the new employee orientation guidelines will make sure that employees are aware of the ramifications of inappropriate use of company resources such as storage.

Theme4 - Type of IT administration to monitor and control growth of data

The theme revealed a need for IT administration to monitor and control data growth affectively. Some of the various methods include manual administration, and the use of applications like StorageX and Tree Size Professional. The use of any one software application to monitor data growth is not applicable. IT professionals seem to have a favorite software application that is mostly used. In some cases user intervention is best suited for the organization. Configuring email limits, file share quotas and file type restrictions are some of the administration best practice techniques that apply. A proactive approach to administering and monitoring data growth is important. Interaction between IT professionals and end users is one method. End user interaction, in conjunction with monitoring tools, can be very affective in the administration and monitoring of data growth.

Theme5 - Types of security concerns with poor data management

The results of the study showed many security threats and concerns related with poor data management such as: data loss, viruses, Trojans, hacking, and compromise of confidential data. The results in poor data management can lead to many network related issues. The network related issues related to poor data management include bandwidth issues, packet loss, connectivity failures, and poor network performance. The compromise in confidential data is another security concern related to poor data management. Improving data management requires locking down files and share locations. Locking down USB ports and certain thumb and portable drives is critical in securing company data. Applying anti-virus applications and implementing computer encryption, is another step in ensuring proper data management, to reduce security concerns within an organization.

Them6 - Organizational data theft or loss

The results of the study also made multiple references to possible data theft or loss. Experiences ranged from recoverable, to total loss because of bad backups. Every organization, whether they know it or not has had some sort of data loss, potentially it is an employee accidently deleting a file or saving over the wrong file. The study revealed 12 out of 20 participants had experienced some sort of data theft or data loss. The 60% of IT professionals who participated in the study experienced some sort of organizational data theft or loss. The percentage of data theft or loss is a high number. The study revealed 8 out of 20 participants as not knowing or not experiencing any sort of organizational data theft or loss.

Theme7 - Concerns with data management in IT field

Results of study expanded on the theme and made references to security, data loss, and storage of unnecessary files, bandwidth, and networking issues. Various concerns surround data management in the IT field. Some of the concerns include: employees saving personal information and taking up valuable network resources such as storage. Many of the organizations deploy storage technology without paying enough attention to the activities taking place on the network. IT professionals expressed personal experiences of end users using network storage as personal dumping grounds for various file types. Participant IT19 stated “it becomes a dumping ground for them for all of their files such as word files, spreadsheets, .pdf’s, .pst’s, PowerPoint’s, and some instances music and picture files.” These sorts of concerns need to be addressed by IT leaders to better handle resources.

Theme8 - Capacity of data storage environment

The results of the study showed varying capacities of data storage environments. For many organizations the capacity will depend on size of the organization and network. Many of the IT professionals find calculating data storage difficult because of personal hard drives, USB

drives, flash drives, and other storage hardware that is made available to end users. Some of the participants in the study did not know the current capacity of their data storage environment because of their role in the IT department or organization. The findings of the study did reveal that storage typically seems to be in the terabytes and gigabytes with the creation of larger and faster storage technology.

Theme9 - Type of storage technology for primary data

The results of the study showed primary data for participants residing on hard drives, varying from standard hard drives, fibre channel, SCSI, SAN, and NAS devices. Some mentions of brand names were made in reference to NetApp and Xiotech. The primary technology used currently by the participating IT professional range from SCSI, fiber channel to regular hard drives. Many of the participants had heterogeneous storage environment where both SAN and NAS were present or SCSI and fiber channel were present.

Theme10 - Refresher courses for employees

The results of the study showed that the majority of the participants did not have any sort of knowledge or refresher course for employees. The need for refresher courses is necessary for IT leaders and their organizations. The refresher course will provide end users the opportunity to be reeducated on policies and procedures. Four of the participants had refresher courses in place for end users within their organization. Creative methods to refreshing users include using videos, setting up classrooms, brown bag lunches, or quarterly communications. Participant IT15 has already implemented a creative method by offering multiple methods of communication "you can go online and click on the videos to refresh yourself or you can sign up, you can just request in the, our training department, you can request a particular class, and they'll put you on the schedule for it."

Theme11 - Time spent administering data content and management

The results of the study showed varying degrees of time spent administering data content and management by IT professionals. Administering data is very important in data storage administration. The participants spent a varying amount of time administering data content and management. The methods varied in administering data content and management. Time spent on administering data content and management ranged from 20%, two hours, to six hours at a time. Depending on the role and responsibility of the IT professional there were varying degrees of time spent administering data content and management

Theme12 - Percentage of unstructured data for data center storage

The results of the study showed a varying amount of unstructured data on data center storage. The level of unstructured data ranged from as low as 10% to as high as 90%.

Unstructured data seems to be unavoidable because of the nature of storage and data. Some of the participants were unaware of the percentage of unstructured data for their data center storage. Calculating unstructured data, from participant responses, seems to be very difficult because data is always changing and can reside in multiple locations on the network. Participant IT07 commented they "don't really have the technology to get a hard number."

Theme13 - Available data investigation content management programs

The results of the study showed various data investigation and content management programs as available to IT professionals. The applications included manual investigation, human interaction, searches, TreeSize, and StorageX applications. Some of the participants were not familiar with any sort of data investigation content management programs. Participant IT15 performed the calculations manually which required substantial time. A data investigation and content management program is useful in administering data storage and content.

Theme14 - Data storage technology

The results of the study showed various data storage technologies available to IT professionals. Many of the participants shared their perception and experience with SAN, NAS, and shared storage. The participants all had some sort of data storage technology implemented in their IT infrastructure. Data storage technology ranged from personal hard drives and flash drives, to high end enterprise level storage arrays with redundancy.

Theme15 - Data backup techniques

The results of the study showed various data backup techniques such as disk to disk backups, virtual tape libraries, tape backups, and SQL (Structured Query Language) backups. The data backup techniques differed among IT professionals, depending on environment, and personal preference in backup techniques. Some participants engineered data backups around the type of server environment they were supporting.

Theme16 - Types of professional development training.

The findings of the study resulted in SNIA, Microsoft track, Cisco track, knowledge sharing, and knowledge transfer. The participants of the study were aware of some professional development and training for IT professionals. Some of the participants shared personal experiences with regards to, professional development. Some of the participants did not know or were not aware of any sort of professional development for IT professionals pertaining to data storage.

LIMITATIONS AND RECOMENDATIONS

One of the identified limitations that became apparent in the study included the interview of IT professionals in a limited geographic location including the state of Virginia, Texas and Washington DC. Therefore, the study did not represent the expressed opinions or thoughts of IT professionals throughout the IT field. Other limitations to the study included a population sample of only 20 participants. The honesty of the participants became a limitation in the study. The participants of the study could skew answers because of preconceived notions, title of the phenomenological study and description of the study. During some discussions with participants additional questions were asked to further the discussion and help obtain rich and detailed descriptions (Moustakas, 1994). During the interview process with participants all were asked the same 16 interview questions. Some participants were asked additional questions during the process to obtain a more detailed description and further the discussion with the participant.

The results of the study only focused on IT policices and procedures in regard to data storage and unstructured data. The purpose of this qualitative phenomenological study was to explore from a purposive sample of 20 IT professionals (managers, engineers, administrators, and analysts) from Virginia, Texas and Washington DC. The aim of the study was to seek and learn their perceptions on how and why data storage decisions were made by exploring contents of network storage and IT policies against unstructured data on a corporate wide network. The study revealed more questions in regards to IT professionals, technology, and leadership. Storage technology and the identification of unstructured data is a small part of IT, and a lot of activities and concerns surround technology within an organziation.

During the interview process, with participants, some refrences were made to virtualization and the implementation of virtualization technology by IT professionals. A furthur study into the affects of virtualization on storage and the development of a new type of unstructured data type is recommended. The phrase "server sprawl" refers to the random excessive creation of virtual servers. Virtual servers are stored on more expensive, high availablity, high speed storage devices. With server sprawl, valuable storage space can be depleted by the creation of servers that are irrelevent to daily business operations. It is recommended that future research be conducted on the cost of data storage as well as the cost of operating storage containing unstructured data.

During the interview process with participants references were made to the decrease in cost associated with purchasing storage but the increase in operating costs of poorly managed storage. Poorly managed storage with a high volume of unstructured data can cause high input and output traffic and degragation of storage performance. The increase in input and outpt can cause latency, bandwidth consumption, and packet loss within organziations network. A furthur study into the affects of unstructured data on network availability and operating costs could provide leaders with methods on how to manage corporate data storage efficiently.

CONCLUSIONS

The purpose of this qualitative phenomenological study was to explore from a purposive sample of 20 IT professionals (managers, engineers, administrators, and analysts) from Virginia,

Texas and Washington DC. The aim of the study was to seek and learn their perceptions on how and why data storage decisions were made by exploring contents of network storage and IT policies against unstructured data on a corporate wide network. The aim of the study was to understand the perception and experience of IT professionals regarding how and why data storage decisions are made. The major themes that emerged from the study data analysis included: strategies to manage data, policies and procedures needed to control unstructured data, new employee orientation, type of IT administration to monitor and control growth of data, types of security concerns with poor data management, organizational data theft or loss, concerns with data management in IT field, capacity of data storage environment, type of storage technology for primary data, refresher courses for employees, time spent administering data content and management, percentage of unstructured data for data center storage, available data investigation content management programs, data storage technology, data backup techniques, and types of professional development training.

Conclusion 1 – Developing Policies and procedures

The findings from the study aim to provide recommendations to IT leaders and IT professionals on how to better control unstructured data, build policies and procedures, educate end users, and guide better data management. The findings of the study supported an important need to develop strategies to manage data. Strategies can differ between organizations, based on organizational needs and organizational wants of leaders. There is a need to develop policies and procedures to control unstructured data. Creating, documenting, presenting and enforcing IT policies and procedures are recommended to IT leaders and IT professionals.

Conclusion 2 – Enforcing Policies and Procedures

In order to enforce IT policies and procedures there needs to be new employee orientation to familiarize end users with company policies and procedures. In addition, workers should sign an end user agreement. IT administration to monitor and control data growth is recommended to leaders and IT professionals. The findings of the study supported the importance of proactively administrating data and taking precautionary measures to control unnecessary data growth and overabundance of unstructured data.

Conclusion 3 - Security

Research showed that there is a need to recognize possible security concerns associated with poor data management. IT leaders and IT professionals both have a fiduciary responsibility to secure data in its entirety. With security concerns like viruses, malware, Trojans, and various other intrusions, there is the need to recognize organizational data theft or loss. Poor data management and undeveloped IT policies and procedures pose a concern with data management in the IT field.

Conclusion 4 – Data Sprawl

Research showed that there is a need for IT professionals and leaders to recognize the capacity of their data storage environment and evaluate the data that is stored on the technology. Adding more storage can easily become a normal practice for many IT professionals and leaders. More storage capacity is not always the best solution for organizations. Research showed that there needs to be control over adding more storage to the IT infrastructure. Data exists in multiple forms, network locations, and on different servers. This can result in data sprawl which can simply be defined as the spread of data with no means of controlling. Data sprawl can result in an impact on productivity, duplicate files, data loss, litigation risks and higher than normal network utilization.

Conclusion 5 – Classification of Data

The findings of the study supported a need for IT professionals and leaders to recognize the type of storage technology their primary data resides on. A good starting point for any IT professional and leader is to classify data as primary, archive, or backup data, using the Duplessie's information lifecycle management approach. Information Lifecycle management allows for information technology professionals to manage information through its lifecycle.

Conclusion 6 – Refresher Course

Research showed that there is a need to implement a refresher course for employees. Refresher courses provide an opportunity for Human resources and IT to coordinate changes in policies and procedures. Changes in information technology policies and procedures can be coordinated with the organizations human resources department to meet compliance with organizational, state and federal regulations. Additionally, development, evaluation, training, and needs evaluations can all be coordinated with human resources.

Conclusion 7 - Administration

The findings of the study supported time spent administrating data content and management. Research showed that IT professionals and leaders need to dedicate resources to administrating data on company storage. Spending time administering and managing data content may provide IT professionals with the percentage of unstructured data residing on their storage environment. There is a need for IT professionals and leaders to recognize that there are available data investigation and content management programs to better label and manage unstructured data. Many data storage technologies are available to transport, archive and backup different data types such as primary, archive and backup data.

Conclusion 8 – Data Backups

Research showed that there is a need for IT professionals and leaders to recognize the different types of backup techniques available to better backup and protect organizational data. Data protection is an insurance plan for organizations. Creating a proper backup plan takes time to create and implement. Identifying critical and non-critical data is important in the classification of backup data. Data backups ensure integrity, security, and availability of computer systems and data.

Conclusion 9 – Professional Development

The findings of the study supported different types of professional development and training. Research showed that there are available professional development for IT professionals and leaders to assist in better managing data and storage. The Internet, technologies, major vendors, schools, and knowledge sharing are, available resources to enhance and deliver education and training to IT professionals and leaders. Providing programs and services to technology professionals can promote professional and personal growth. There is a need to provide a variety of training and development opportunities through the use of workshops, certification programs and vendor specific training.

Conclusion 10 – Knowledge Transfer

Findings also support the conclusion that by acknowledging the challenges faced by IT leaders and IT professionals in managing technology, both leaders and IT professionals can work closely with one another to share and transfer knowledge. By working closely with one another both IT leaders and IT professional can build policies and procedures, and administer data efficiently. The sharing and transfer of knowledge, implementation of policies and procedures, and administering of data could provide the ability to be able to carry out practices that meet or exceed the vision of the organization. IT Leaders who can display creativity, provide insight, stay persistence, display high energy, and intuition could provide the ability to keep in line with the organization's vision.

REFERENCES

Bradshaw, R., & Schroeder, C. (2003). Fifty years of IBM innovation with information storage on magnetic tape. *IBM Journal of Research and Development, 47*(4), 373-383.

Booth, M. E., & Philip, G. (2005). Information systems management: Role of planning, alignment and leadership. *Behavior and Information Technology, 24*(5), 391-404.

Byrd, A, Terry, Lewis, R., Bruce, Bradley V. Randy. (2006). IS infrastructure: The influence of senior IT leadership and strategic information systems planning. *Journal of Computer Information Systems,* 101-113.

Castagna, R. (2008). The Big Pipe. *Storage, 7*(6), pg. 6

Castagna, R. (2008). Storage wishes for 2009. *Storage,* 7(11), pg. 4

Castagna, R. (2008). 2009: Do more with less. *Storage, 7*(11), 30-37.

Creswell, J. W. (1998*). Qualitative Inquiry and Research Design Choosing Among Five Traditions.* Thousand Oaks, CA: Sage Publications.

Creswell, J. W. (2007). *Educational research: Planning, conducting, and evaluating quantitative and qualitative research*. *Third Edition.* Upper Saddle River, NJ: Pearson.

Creswell, J. W. (2007). *Qualitative inquiry & research design: choosing among five approaches Second Edition.* SAGE publication

Goldsborough, R. (2006). The past, and future, of hard drives. *Tech Directions, 66*(6), 12-13.

Hellman, D. J., Yardy, R., & Abbott, P. E. (2003). Innovations in tape storage automation at IBM. *IBM Journal of Research and Development, 47*(4), 445-452.

Hoving, R. (2007). Information technology leadership challenges – Past, present, and future. *Information Systems Management, 24*, 147-153.

Lazarides, T. (2007). Comply! Resistance is futile. Information Management and Computer Security, 15(5), 339-349. Retrieved January 8, 2009,

Maby, M. (2004, September). Matching data to storage. *Computer Bulletin, 46*(5), 22-23.

Moustakas, C. (1994). *Phenomenological research methods*. SAGE Publications.

Nujeerallee, S., & Anidi, D. (2002). Storage area networking - An introduction and future development trends. *BT technology Journal, 20*(4), 45-60.

Polifroni E., C., Welch, M. (1999). *Perspectives on Philosophy of Science in Nursing: An Historical and Contemporary Anthology*. Lippincott Wlliams & Wilkins.

Simon, M. (2006). *Dissertation and scholarly research: Recipes for success. A practical guide to start and complete your dissertation, thesis, or formal research project*. Kendall Hunt Publishing Company

Swartz, N. (2007). Data growth driving archival efforts. *Information Management Journal, 41*(2), 14.

Whitten, D. (2008). The Chief Information Security Officer: An Analysis Of The Skills Required For Success. *The Journal of Computer Information Systems, 48*(3), 15-19. Retrieved January 8, 2009, from ABI/INFORM Global database.

APPENDIX A.

Information Technology Professional Interview Questions

Background info and demographic questions

Focused Questions

This study will be guided by the following question:

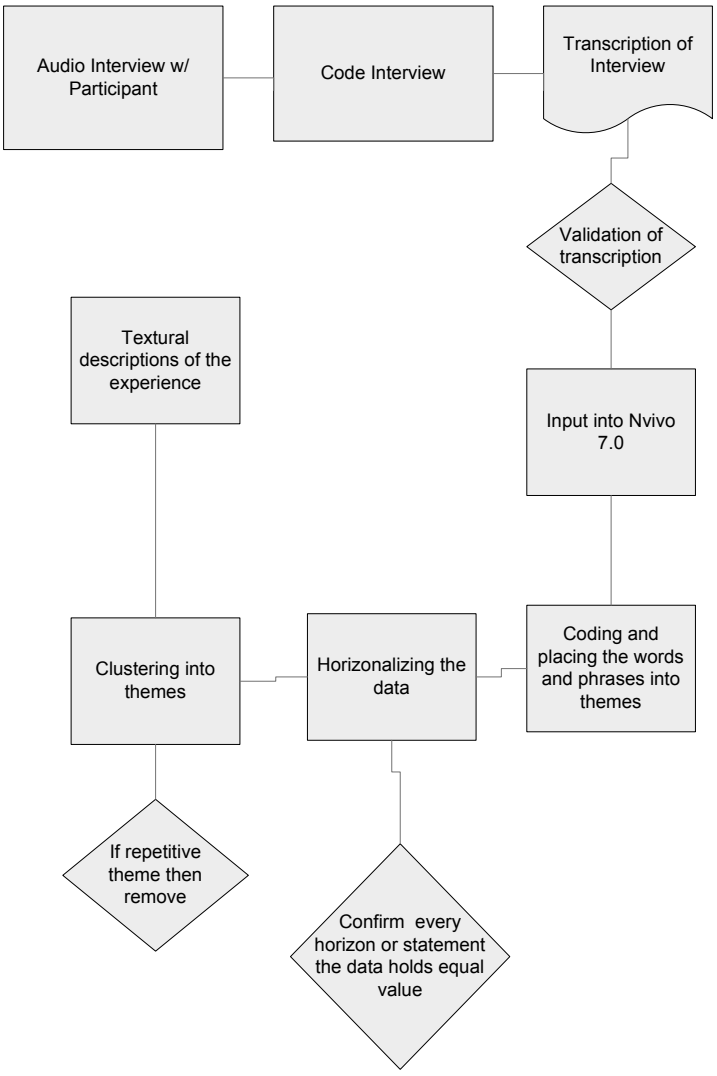
1. As an IT professional, what strategies have you implemented to manage data in your data center?

[Thank the individuals for their cooperation and participation in this interview.
Assure them of the confidentiality of the responses and the potential for future interviews.]

Questions that will assist in this data collection include:

2. Describe your thoughts on the problems associated with data management in the IT field?
3. Describe your thoughts on the policies and procedures that need to be implemented to control unstructured data?
4. What is the current capacity of your data storage environment?
5. What sort of data storage technology are you utilizing in your data storage environment?
6. What type of storage technology does your primary data reside on?
7. What sort of data backup techniques is currently implemented in your data center?
8. What is the percentage of unstructured data that makes up the content in your data center storage environment?
9. What sort of new employee orientation does your organization provide to educate employees on IT policies and procedures?
10. What sort of employee orientation renewal course is available to refresh employees on IT policies and procedures?
11. What sort of IT administration is carried out to monitor and control the growth of unstructured or unwanted data?
12. What sort of data investigation or content management programs is available to IT professionals to assist them with the difficulties of managing data storage?
13. What type of professional development or training is available for IT professionals that may assists in better data management techniques?
14. How much time during the course of a work day is spent on administering data content and management?
15. What sorts of security concerns become apparent in poor data management?
16. Has your organization ever experienced any sort of data theft or loss?

[Thank the individuals for their cooperation and participation in this interview.
Assure them of the confidentiality of the responses and the potential for future interviews.]


Audio Interview w/ Participant
Code Interview
Transcription of Interview
Validation of transcription
Input into Nvivo 7.0
Coding and placing the words and phrases into themes
Horizonalizing the data
Clustering into themes
Textural descriptions of the experience
If repetitive theme then remove
Confirm every horizon or statement the data holds equal value

A SYSTEMATIC APPROACH FOR VSM-BASED WEB PAGE CLASSIFICATION

Lei Li, Columbus State University
Vijay K. Vaishnavi, Georgia State University
Art Vandenberg, Georgia State University

ABSTRACT

Effective and efficient Web information classification becomes increasingly important as the Web continues to grow exponentially. Vector space model (VSM) is a traditional algorithm used to classify Web pages. However, VSM's effectiveness largely relies on selecting appropriate parameter values and such selection is often done in an ad hoc manner. Another challenge is the performance of VSM, especially when the classification algorithm processes large data sets. This paper describes a systematic approach for Web page classification that addresses both of these challenges. A genetic algorithm (GA) is integrated with VSM for the selection of appropriate parameter values and the integrated algorithm is enhanced to run in a grid-computing infrastructure. By utilizing GA to discover VSM parameter values set, the effectiveness of VSM is greatly improved. By applying grid, it becomes possible to efficiently deal with large data sets. A preliminary research prototype has been implemented and used to conduct empirical studies. Results of the experiments are reported and discussed.

Keywords: Web Page Classification, VSM, Genetic Algorithm, Grid, Systematic Approach

INTRODUCTION

There are billions of Web pages on the World Wide Web and the number continues to grow exponentially. People are relying on commercial search engines such as Google (www.google.com), Yahoo (www.yahoo.com), AltaVista (www.altavista.com/), etc., to retrieve information from the Web. Search engine results are often loosely classified according to keyword matches, link analysis or other mechanisms. Search engines provide a good start for information retrieval but may not be sufficient for complex information inquiry tasks that require relevant classification of a large volume of results. Indeed, numerous studies (Fairthorne 1961; Hayes 1963; Attardi, et al. 1999; Craven, et al. 2000; Flake, et al. 2002; Kennedy and Shepherd 2005; Calado, et al. 2006; Kousha and Thelwall 2007) have demonstrated that appropriate classification of search results can greatly improve the efficiency of information retrieval.

Consider the following real world use case that we subsequently refer to as the SURA project. SURA (Southeastern Universities Research Association, www.sura.org) has a strategic

initiative to develop cyber infrastructure such as grids for its 62 member universities. SURA wants a knowledgebase of all researchers who have grid-enabled applications or grid-potential activities. Since search results from commercial search engines can include too much irrelevant information, an initial knowledgebase of faculty research pages from nine SURA sites was compiled manually – a task requiring dedicated staff several months in browsing each university Web site, locating and evaluating relevant pages about faculty researchers, and storing results in a database. While initially useful, such a database quickly grows stale as pages change or whole sites revise their content. Moreover, SURA ultimately wants all 62 university Web sites to be similarly processed, a rather impractical, un-scalable approach. Indeed, browsing each of the 62 Web sites is a cumbersome, impractical task – each university site contains millions of Web pages.

To address the problem posed by the SURA project, it is important to develop an effective and efficient approach to automatically classify large volumes of Web pages. In this paper, we introduce a systematic approach that integrates vector space model (VSM) based classification algorithm, genetic algorithm, and grid computing infrastructure to effectively and efficiently classify Web pages.

The rest of the paper is organized as follows. Section 2 provides an overview of related research about Web page classification. Section 3 discusses the proposed research approach in detail and presents the prototype development work. Section 4 describes the experiment design and results. Section 5 concludes the paper and summarizes its contributions and future directions.

RELATED RESEARCH
WEB INFORMATION CLASSIFICATION

As the number of Web pages grows exponentially, people rely on search engines to find relevant information. However, even powerful commercial search engines such as Google may be inefficient for complex information inquiries due to large amount of information involved. Classification, especially automatic classification, has been widely used to improve the quality of Web search. Fairthorne (Fairthorne 1961) and Hayes (Hayes 1963) demonstrated that the classification process greatly improves the efficiency of information retrieval. Figuerola et al. (Figuerola, et al. 2001) compared the results of automatic categorization and manual categorization of documents in Spanish. They concluded that the results obtained from manual classification did not differ greatly from that of automatic categorization mechanism. Attardi, et al. (1999) proposed an automatic Web classification approach by applying link and context analysis. The open issue in their method is that by allowing the classifier itself to crawl freely among sites, they cannot cover large sets of Web pages.

Flake, et al. (2002) showed that using URLs and HREF links alone can organize pages into community groups. They, however, do not address the computational performance of their approach, nor do they discuss how quickly they could crawl and parse the Web pages. Kennedy

and Shepherd (2005) use a neural network based classifier to distinguish home pages from non-home pages, and to classify home pages as personal, corporate, or organizational home pages. Their experimental data sets are rather small and are processed using computation intensive neural network classifiers – an approach that may not scale for large or varied datasets. In addition, their experiments do not measure the processing time of their approach. Craven et al. (Craven, et al. 2000) apply machine-learning algorithms to create a computer understandable knowledge base, whose content mirrors the World Wide Web, and use that information for more effective Web information retrieval. Their experiment is limited to Web pages from four different departments of a university and does not address scalability of the system.

In summary, many of Web classification studies have focused on showing the effectiveness of their approaches. However, few research studies investigate the efficiency of their classification approaches and how their approaches scale up. Efficiency and scalability could be a critical issue when the information retrieval task involves handling large amount of data as is the case for the SURA project discussed in the introduction.

VECTOR SPACE MODEL AND WEB CLASSIFICATION

Vector space model (VSM) (Salton, et al. 1975) is a mathematical model to represent text documents as vectors of keywords (tokens).Vector space model is widely used in information retrieval and Web classification applications (Attardi, et al. 1999; Craven, et al. 2000; Figuerola, et al. 2001; Tai, Ren et al. 2002; Flake, et al. 2002; Metikurke, et al. 2006). Salton (Salton 1991) did an experimental study demonstrating that classic information retrieval such as a vector model outperforms other information retrieval models (such as a probabilistic model) for general collections.

The vector space model based Web classification algorithm generally includes three steps. The first step is tokenization where keywords that represent the content are extracted from the Web pages. A list of "stop" word is removed (stop words in our case being from Google Search = "common words in English," plus punctuation and non-alphabetic terms, and words of less than 4 characters.) The second step is the weighting of the indexed keywords to improve the relevance of the classification; the third step classifies the Web pages based on matching of keywords identified in step 2 with each individual Web page. While VSM has been successfully applied in Web classification applications, its procedure is often criticized for being ad hoc (Raghavan and Wong 1986). The performance of VSM based classification algorithm highly relies on the selection of VSM parameter values such as which portion of pages should be used as training dataset, what keywords should be used for classification, or what threshold value should be used for pattern matching. The selection of good VSM parameter values for an application domain is often done in an ad hoc manner or using a trial-and-error approach. Theoretically one can sequentially test all possible combination of parameter values in the search

space in order to find the best VSM parameter value set. However, the search space is typically very large and thus a sequential search process can be very time consuming.

VECTOR SPACE MODEL AND GENETIC ALGORITHM

In this paper, we propose to use a genetic algorithm (GA) (Holland 1975) to systematically discover optimal or near-optimal VSM parameter values. A genetic algorithm mimics the human evolution process and is commonly used to solve optimization problems. Compared to traditional search algorithms, a genetic algorithm can automatically acquire implicit knowledge about the search space during its search process, and proactively direct the search process through a random optimization technique.

GA is intrinsically parallel in nature. VSM parameter values selection process described in Section 2.2 is serial and it can only explore the solution space in one direction. For example, if the parameter values selected are suboptimal, the algorithm has to discard the result and repeat the process from start, with another limited and unidirectional attempt. However, since a GA has multiple offspring, they can search a solution space in several directions at once. If one of the directions turns out to be sub-optimal, GA can discard those results and continue to process in other directions chosen by other offspring to find a more promising solution. Thus, GA's are well suited to performing non-linear, exhaustive search to solve problems with a very large solution space.

In addition, GA can often yield the globally optimal solution, while avoiding combinatorial explosion, by disregarding certain parts of the search space (Wu, et al. 2004). Pathak et al. (Pathak, et al. 2000) used GAs and a vector space model as the underlying model to adapt matching functions that match document descriptions with queries. In summary, the genetic algorithm seems to be an appropriate approach to find optimal VSM parameter values.

GRID COMPUTING INFRASTRUCTURE

Performance efficiency could be a bottleneck for Web classification approaches when handling a large number of Web pages. Especially when a computational-intensive genetic algorithm is used to search optimal VSM parameter values, the performance issue becomes even more prominent.

A computational grid (Foster, et al. 2002) as "a hardware and software infrastructure that provides dependable, consistent, pervasive and inexpensive access to high-end computational capabilities" could be a good solution to improve the efficiency of Web classification algorithms. Grid computing infrastructure provides enormous computation and resource sharing capability as well as a user level abstraction in accessing the computation resources (shielding the user from detailed specifics of these resources).

Grid is suitable to applications that can be parallelized. Large Web classification tasks can be divided into small tasks that are executed independently. A genetic algorithm is parallel by its very nature and so well-suited for a grid approach to help Web classification algorithm to process large volume of Web pages. The research question is how to seamlessly integrate VSM classification algorithm, grid, and GA together.

PROPOSED APPROACH

We introduce a systematic approach that can automatically classify Web pages. We use vector space model as the classification algorithm because it has proved to be effective and it is not computationally intensive (given parameter values are known). We innovatively integrate VSM with genetic algorithm and grid computing infrastructure to improve the effectiveness and efficiency of the approach. We argue that applying a genetic algorithm can systematically discover a good VSM parameter value set that can improve the effectiveness of the approach. We also use the grid infrastructure to supply computing power for processing large amount of Web pages. The proposed approach is illustrated in Figure 1.

The approach has four major components: Information Retrieval Module, Pattern Generation Module, Web Page Classification Module, and Grid Infrastructure Module. We use the SURA case to illustrate the functionality of each module in detail.

Information retrieval module. The purpose of this module is to extract the Web resources of user interests (candidate Web pages such as SURA university Web sites) from the World Wide Web using a Web crawler. We use Google Web crawler since Google is a standard search engine for web search. Since the (SURA) case is about faculty (home) pages, the initial data set for classification is obtained through a Google advanced search query that uses keywords (see section 4.2) identified by Kennedy and Shepherd's algorithm (Kennedy and Shepherd 2005) to identify home pages. The candidate Web pages are cached for later processing by the pattern generation module and Web page classification module.

Information Retrieval Module are first parsed, their content is tokenized and compared to the Web page pattern produced by Pattern Generation Module, and the candidate pages are classified as conforming to the Web page pattern or not. The set of Web pages matching the pattern are classified as the pages relevant to user interest.

Keyword Pattern Generation Module. This module can generate a Web page keyword pattern that is used in the classification phase. The pattern generation process is often called a training phase for VSM classification algorithm. The training dataset is drawn from a collection of Web pages that is representative of the targeted Web information. For example, in the SURA project, faculty Web pages needs to be identified so a set of SURA faculty Web pages might be chosen as training data set. Pattern generation then creates a pattern (such as keywords that occur above a certain frequency range on relevant pages) based on the training dataset. These keywords provide the pattern used in the process of classification of subsequent Web pages as

SURA faculty pages. Genetic algorithm is used as a search mechanism to discover optimal parameter values that can provide better classification results. Specifically, there are three important VSM parameters manipulated by GA.

- Percentage of URLs for training (pnu) – the percentage of available training pages actually used for training. The percentage should not be too large or too small.
- Percentage of number of tokens (pnt) – Tokens (keywords) first are extracted from the training pages and ranked based in decreasing order of their frequency of occurrence; pnt refers to the percentage (starting from the most frequently occurring word) of these words used in the keyword pattern.
- Threshold percentage (tp) – the percentage of keywords in a Web page that should match with the Web page pattern for that page to be identified as page relevant to user interest.

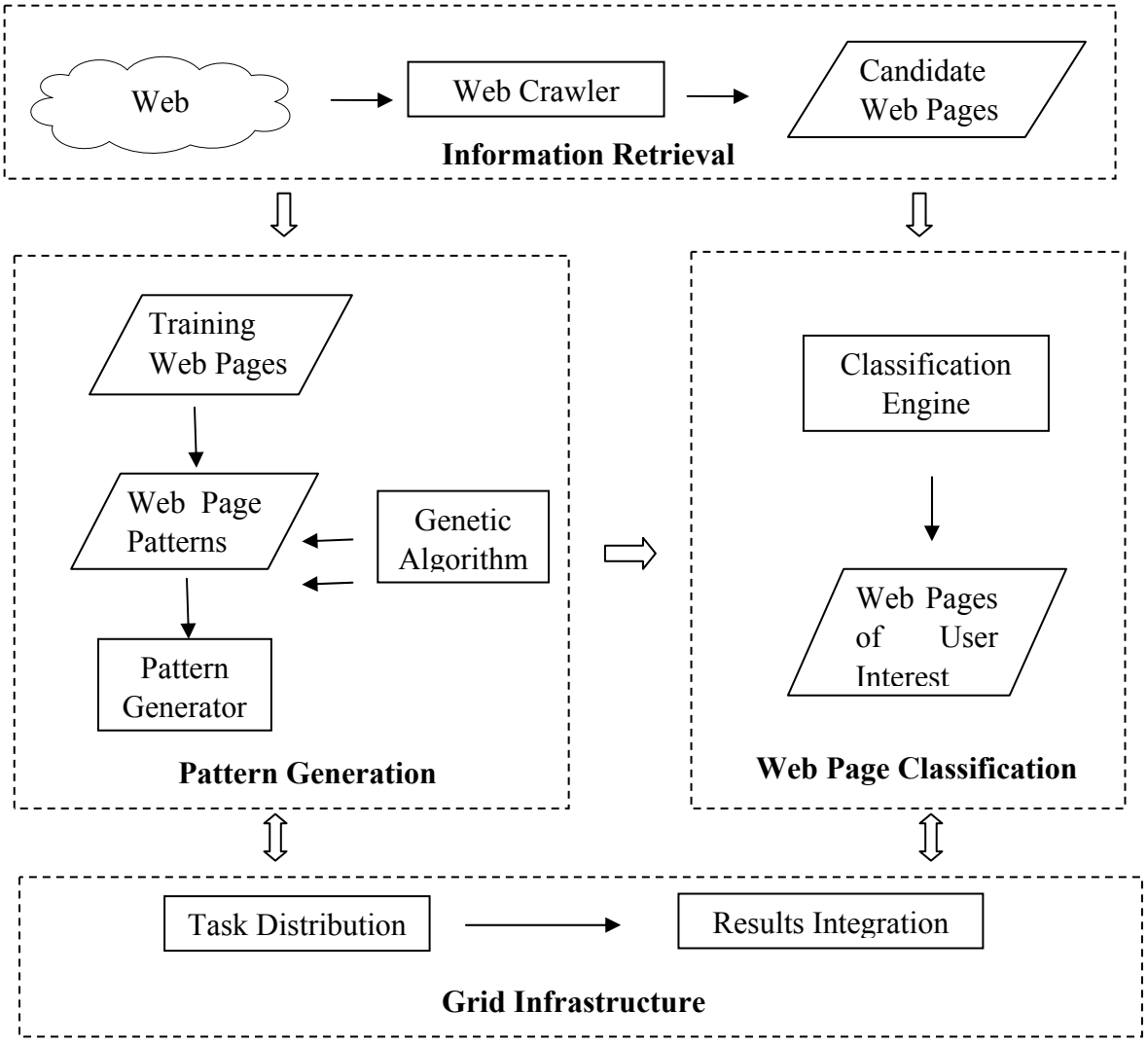


Figure 1. The Proposed Research Approach

Web Page Classification Module. In this module, the candidate Web pages collected by information retrieval module are first parsed, their content is tokenized and compared to the Web page pattern produced by pattern generation module, and the candidate pages are classified as conforming to the Web page pattern or not. Finally, a set of Web pages of are classified as the pages of user interest.

Grid Infrastructure Module. Grid infrastructure supports other modules by supplying computing power. A grid is composed of a set of compute nodes. The master grid node divides the main task into smaller tasks. For instance, when needing to classify Web pages from many Web sites, the task distribution process can divide Web sites into many small groups and then each group of Web sites is distributed to a grid node for processing. The grid nodes perform the assigned tasks concurrently. The classification result of each grid node is sent back to the master grid node and becomes input to the result integration process.

RESEARCH PROTOTYPE DEVELOPMENT

In order to demonstrate the feasibility of the proposed approach and to carry out experiments, a preliminary research prototype has been developed.

The Web crawler is written in Java programming language. Using the keywords recommended by Kennedy and Shepherd (2005) to identify home pages, the crawler first generates a URL list of home pages using Google advanced search, then retrieves content of those Web pages using the "Save Page As" feature of the Web browser. The retrieved Web pages are saved to computer hard drive as a text file. This save is done for two reasons: 1) The content of Web pages is used multiple times during the training and classification process, so having pages available locally can greatly reduce processing time; and 2) as the content of Web pages may change as time goes by, saving the files can ensure the comparability of the experiments conducted over time.

The classification engine is a collection of Java programs including those for tokenization and classification of the Web pages. In the tokenization process, keywords that represent the content are extracted from the Web pages and a list of "stop" words such as common English words, punctuation or other non-alphabetic terms are removed from the keywords list. The classification engine checks each candidate Web page to see if the tokens extracted from page match with the keywords in the Web page pattern. If the number of the matches exceeds the predefined threshold, the Web page is classified as the page of user interest.

Grid computing infrastructure provides computing power for the Web Classification Module and Pattern Generation Module. The Grid used in this research prototype is a small-scale in-house Grid implementation (as shown in Figure 2) that contains 13 nodes (each Grid node is a Dell PC with 933 MHz CPU and 512 MB RAM). Globus Toolkit™ (GlobusAlliance 2005), built on the Open Grid Services Architecture (OGSA) open source software, is used for a higher level of resource management services (e.g., sharing computational and other resources without

sacrificing local autonomy). PBS Pro (Portable Batch Scheduler Professional) is used to make the Grid system call for submitting tasks to Grid nodes, scheduling the tasks for running, executing tasks, and collecting the results. The task distribution and result integration functions are Java programs that use Linux bash shell script to run corresponding PBS Pro commands.
The pattern generator is composed of a set of Java programs including those for selection of training Web pages, tokenization of the Web pages, calculation of the keywords frequency among the Web pages, and selection of Web page patterns. A genetic algorithm coordinates the process by varying the parameter values for pattern generations, such as what portion of candidate Web pages should be used as training pages or which keywords should be included in the Web pages pattern. The genetic algorithm component is implemented using an open source software package, GAlib (GAlib 2005).

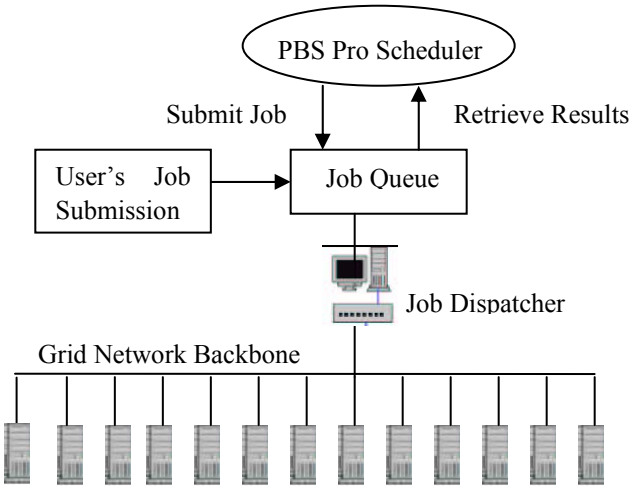


Figure 2. Grid Infrastructure Architecture

The grid-computing infrastructure is integrated with computational-intensive genetic algorithm to improve its performance. The program flow of grid enhanced GA algorithm is illustrated in Figure 3. First, the VSM-based classification program and required dataset are copied to each grid node for future execution. GA program runs from the grid master node. GA first generates an initial population (first generation) of genomes (genomes are, effectively, codings of parameter values). GA decodes each genome by mapping them into VSM parameter values set and creating a corresponding command line for classification program. GA then converts the command line into a PBS (Portable Batch System) script and submits it to PBS Pro scheduler of grid job queue. The job queue dispatches the jobs (PBS scripts) to available grid nodes on which the classification program is executed using command line embedded in the PBS script. The running result of the classification program, the F-measure which is widely used to

measure the effectiveness of web classification algorithms, is sent back the master grid node and is used as the fitness measure of the genome associated with the task. GA collects the running results of all genomes in a generation and then tests whether the termination condition is met (e.g., the difference between the average fitness value of current generation and the average fitness value of previous generation is smaller than a specified threshold). If so, GA program ends. Otherwise, GA performs selection, crossover, or mutation operations (GA operations are modeled on human genetic changes) to create a new population for the next generation. The process of decoding genome, generating PBS script, dispatching tasks to grid, collecting results from grid node, testing termination condition, and generating a new generation (if necessary) can be repeated many times until the termination condition is satisfied. When the GA program finishes execution, the genome that has the best fitness value of the last generation is selected as the best VSM parameter value set.

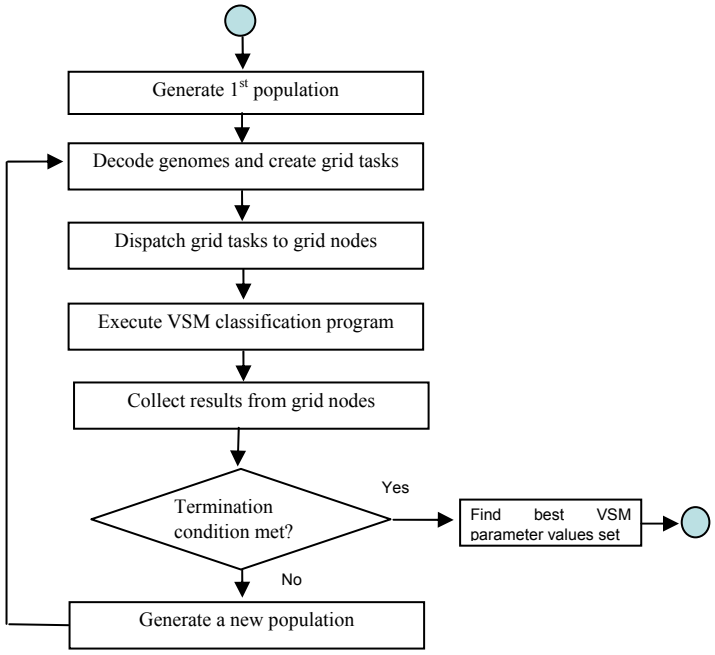


Figure 3. Program Flow of Grid-enhanced Genetic Algorithm Component

EXPERIMENTS AND RESULTS

EXPERIMENT DESIGN AND RESEARCH HYPOTHESES

The effectiveness of the VSM-based Web classification system highly relies on the selection of its parameter values. Traditionally, the selection of VSM parameter values is done in an ad hoc manner. A more systematic approach would be to sequentially try many possible combinations of VSM parameter values in order to find a set for good classification performance. We call this method as sequential search and argue that a sequential search could

discover a good set of VSM parameter values if it exhaustively covers the search space. As a starting point, it is useful to validate this statement, leading to the first hypothesis:

H 1. A sequential search method can discover a set of VSM parameter values that can provide effective classification performance.

Sequential search strategy could be computationally intensive because VSM parameter values may have a very large search space. In addition, a parameter value that works well for one domain may not work for another domain (requiring further computation). We use grid-enhanced genetic algorithm as the search mechanism to systematically and efficiently discover the best or near optimal VSM parameter values.

Whereas the solution space for VSM is large and the sequential search method can only explore small portion of the space (and only searching in one direction), the intrinsically parallel genetic algorithm can search the solution space in several directions at once. If one direction turns out to be sub-optimal, GA can discard those results and continue to process in other more promising directions to find an optimal solution. This leads to the following hypothesis:

H2a. Genetic algorithm can discover a set of VSM parameter values that provide equal or more effective classification performance than the VSM parameter values identified by sequential search.

Genetic algorithm can often yield a globally optimal solution, while avoiding combinatorial explosion, by disregarding certain parts of the search space. Thus, GA could use less time to discover a similar level of solution than sequential search does. This leads to hypotheses H2b:

H2b. Genetic algorithm could use less time than sequential search in discovering a set of VSM parameter values that provide similar or more effective classification performance.

We are also concerned with the efficiency (performance time) of Web classification approaches and proposes to use grid infrastructure to provide computing power to the proposed research. There is coordination overhead in the use of grid computing but in this case the overhead is expected to be minimal. This leads to the third hypothesis:

H3. The developed Web classification approach using grid computing infrastructure takes less time to accomplish the classification task than an approach that does not apply grid infrastructure.

Three experiments are designed to test the above three hypotheses, respectively.

DATASET SELECTION

The dataset was obtained by a Google search on six SURA universities. The Google Search used a pattern suggested by Kennedy & Shepherd (2005) for classification of home pages: pages having all three words <faculty, professor, email>, either of the words <he, she>, and with pages being from the domain of a university (cf. <university>.edu.)

In Experiment 1 and Experiment 2, a set of 545 Web pages from SURA universities were used as dataset. The 545 pages were randomly organized and indexed. Two thirds of these 545 Web pages (363 Web pages) were randomly selected as potential source for training dataset. Out of those 363 Web pages, 250 were, in fact, faculty Web pages. These 250 Web pages were used as training dataset. The remaining one third of dataset (182 Web pages) was used as potential testing dataset for classification. The testing dataset was further randomly divided into 2 groups: Testing Dataset 1 (121 pages) and Testing Dataset 2 (61 pages). In Experiment 3, 1686 Web pages from six SURA universities were used as the dataset.

All extracted Web pages were cached to computer hard drive to improve efficiency of the processing and ensure a common base for comparability across different experiments.

EVALUATION METRICS

We use standard metrics in the information retrieval domain, precision and recall, to measure the effectiveness of the Web page classification approach.

Recall(R) = number of retrieved and relevant documents / number of relevant documents
Precision (P) = number of retrieved and relevant documents / number of retrieved documents

A standard evaluation metric for overall classification performance (effectiveness) is F-measure value (Van Rijsbergen 1979; Larsen and Aone 1999; Stein and Eissen 2002; Kennedy and Shepherd 2005; Fersini, et al. 2008). F-measure is a mechanism to provide for an overall estimate of the combined effect of Recall and Precision. The F-measure formula is expressed as:

$$F - Measure = \frac{(BETA\text{^}2 + 1) * R * P}{(BETA\text{^}2 * P) + R}$$

BETA is the relative importance of Recall vs. Precision – a BETA value of 0 means F-Measure = Precision and BETA value of ∞ means F-Measure = Recall. (For instance, BETA=1 means Recall and Precision are equally weighted; BETA=0.5 means Recall is relatively less important than Precision; BETA=2.0 means Recall is relatively more important than Precision.) We set the value of BETA to be 1.0, assigning equal importance to Recall and Precision. A higher F-Measure indicates a better overall classification result – Recall and Precision are both improved.

EXPERIMENT 1 - SEQUENTIAL SEARCH

In the experiment, we used sequential search mechanism to discover a good VSM parameter values set. There are three important VSM parameter values.

- Percentage of URLs for training (pnu) – the percentage of the 250 available training pages actually used for training. The percentage value should not be too large or too small. We set it ranging from 5% to 100%.
- Percentage of number of tokens (pnt) – Tokens (keywords) first are extracted from the training pages into a list and ranked in decreasing order based on their frequency of occurrence; pnt refers to the percentage (starting from the most frequently occurring word) of these words used. Here pnt is set to range from 5% to 70%.
- Threshold percentage (tp) – the percentage of keywords in a Web page that should match with the Web page pattern for that page to be identified as page relevant to user interest. We set tp ranging from 10% to 100%.

In the sequential search, we test all combinations of the parameter values in the specified ranges to find the best combination based on the F-measure. We have parameter values increase 10% each time, generating 630 combinations of VSM parameter values sets considered for Testing Dataset 1. The program is executed in a desktop PC (AMD 2.6GHZ due-core processor, 3GB memory, and 500GB hard drive). The results are shown in Table 1.

Table 1: Experiment 1 Results

Item	**pnt**	**Tp**	**pnu**	**Recall**	**Precision**	**F-measure**
Values	5%	80%	95%	0.845	0.557	0.671
Total Running time	225 minutes					

Table 1 shows the sequential search takes considerable amount of time to run yet it discovers a good set of VSM parameter values. A similar study (Kennedy and Shepherd 2005) on Web classification applied VSM to identify personal/organizational home pages and it reported F-measure value ranging from 0.32 to 0.71. This study generates the F-measure value of 0.671. *Thus, Hypothesis 1 can be considered to be supported.*

EXPERIMENT 2

In Experiment 2, we apply genetic algorithm as the search mechanism to systematically discover good VSM parameter values. In order to be comparable to experiment 1, the VSM parameter values are in the same range as in Experiment 1. We tried three different settings of genetic algorithm. In Setting 1, we want to ensure that GA can quickly find a solution, thus a small population size and convergence rate were used. We used a larger population size in Setting 2 to increase the search space to check if GA can generate a better solution. In Setting 3, we applied a very large population size and convergence rate to further increase GA solution

search space (and hence longer running time) to identify an even better solution. The result of the experiment is listed in Table 3.

Table 3 shows that, even for a small population size and convergence rate (Setting 1), the genetic algorithm approach can discover a VSM parameter values set that provides comparable performance as the one discovered by sequential search. But the running time of genetic algorithm (36 minutes) is much less than for sequential search (225 minutes). If we increase the population size to enlarge the search space and increase the convergence rate to make the genetic algorithm search a little longer, parameter values sets that generate better classification performance are identified.

In all three settings, GA can discover a set of VSM parameter values provide equal or better classification performance than the VSM parameter values identified by sequential search. *Thus, Hypothesis 2a is supported.* In both GA Setting 1 and Setting 2, GA approach identifies VSM parameter values that provide equal or better performance than the one discovered by sequential search, but the running time is significantly less than the sequential search. The GA approach takes considerably more time to run in setting 3. However, setting 3 is only used to search the best VSM parameter and isn't normally used in GA settings. *Thus Hypothesis 2b is supported.*

Table 2: Experiment 2 Results

Items	Setting 1	Setting 2	Setting 3
Population size	30	60	100
Mutation	0.18	0.18	0.18
Crossover	0.8	0.8	0.8
Convergence rate	0.9	0.9	0.9999
Best individual (pnt, tp, pnu)	6, 86, 35	24, 85, 7	20, 93, 7
Recall	0.879	0.879	0.862
Precision	0.543	0.580	0.610
F-measure	0.671	0.699	0.714
Running time (minutes)	36	68	332

The above GA-related experiments are run on a desktop PC (AMD 2.5GHZ dual-core processor, 3GB memory, and 250GB hard drive). The GA program takes quite a long time to run in some settings. We re-ran the experiment for Setting 3 using a grid-enhanced GA program in our in-house grid computing infrastructure, the running time was reduced from 332 minutes to 56.8 minutes. The running time can be further reduced if a more powerful grid can be used.

EXPERIMENT 3

This third experiment studies if grid infrastructure can reduce the running time of the proposed classification approach when large volumes of datasets are involved, in spite of the

coordination cost incurred in the approach. To demonstrate this, we query three more SURA universities in addition to the dataset we used in Experiments 1 and 2. The dataset used in this experiment involves six universities.

We first run the classification program on the dataset in a standalone desktop PC (Pentium4 2.4 GHz processor, 40 GB hard drive, and 1GB RAM). We then send the exactly same task to our in-house grid network where the computer nodes in the grid are, by the way, slower machines (Pentium 3 processor with 933 MHz processor, 8.5 GB hard disk and 512 MB RAM). The running times for the two settings are recorded in Table 3 and Table 4, respectively.

Table 3: Running Time of Classification Task on a Standalone Desktop PC (Setting 1)

Domain	Number of Pages	Time per domain (minutes)	Average time per URL (seconds)
university 1	234	4.15	1.06
university 2	130	1.91	0.88
university 3	60	1.13	1.13
university 4	330	4.46	0.81
university 5	162	3.17	1.17
university 6	770	9.04	0.70
Total	1686	23.86	0.85

Table 4: Running Time of Classification Task on Grid (Setting 2)

Domain	Number Pages	Time per node (minutes)				Average URL per Second
		Run 1	*Run 2*	*Run 3*	*Average*	
university 1	234	14.51	18.69	16.86	16.68	4.28
university 2	130	4.96	4.96	6.28	5.40	2.49
university 3	60	4.43	4.21	4.15	4.26	4.26
university 4	330	15.94	19.85	19.13	18.31	3.33
university 5	162	16.16	12.27	12.61	13.68	5.07
university 6	770	8.49	9.12	14.77	10.78	0.84
Total	1686	16.16	19.85	19.13	18.13	0.65

Note: The total running time as experienced by a user equals to the longest running time a grid node.

Comparing Tables 3 and 4, the running time for any individual site in Setting 1 is significantly less than values in Setting 2. This is simply because Setting 1 uses a much faster computer than Setting 2 does. However, the total running time for all sites in Setting 1 is 23.86 minutes – the total of the sequentially processed sites. In Setting 2, we use six nodes in our Grid to process the data from the six universities in parallel: each computer node handles one university dataset. The average running times for each dataset are listed in table 4. The net overall time is effectively the longest average elapsed running time of the six nodes (university 4) at 18.31 minutes. The total running time (to the user) in Setting 2 is significantly less than the running time (to the user) in Setting 1. The time difference, of course, would be much larger if the grid node uses the same type of computers as used in Setting 1. *Thus, Hypothesis 3 is supported.*

CONCLUSION AND DISCUSSION

The classification of information from the World Wide Web is especially challenging given the large volume of data and potentially wide scope of a user's search. This paper describes a systematic approach for Vector Space Model (VSM)-based automatic Web page classification. A genetic algorithm (GA) is integrated with VSM for the selection of appropriate parameter values and the integrated algorithm is run in a grid-computing infrastructure. By utilizing GA to discover VSM parameter values set, the effectiveness of VSM is greatly improved. A research prototype has been implemented and the experiment results demonstrate effectiveness and feasibility of the proposed approach.

The main contributions of this paper are in: 1) Improvement of a classification algorithm by applying a GA that discovers optimal parameter values set for the VSM-based algorithm. 2) Application of grid computing and integration of grid and GA to improve performance of VSM classification program significantly. The research has implications on the field of Web information management. With the exponential growth of World Wide Web, one of the key issues isn't just about finding the information, it is about how to organize vast amount of information generated by Web search. This study promises a systematic approach to organize Web information with minimal human intervention which could significantly improve the effectiveness and efficiency of Web information retrieval.

This study has several limitations. First, the research prototype is preliminary. The classification engine and crawler is written in Java language. The performance of the prototype could be significantly improved if the prototype can be programmed professionally using a different language. Secondly, we used a small in-house grid in this approach. We need to test our approach in a larger or commercial-scale grid environment to validate the performance improvement capability of the system. It would be interesting to study the relationship between grid power and data volume. Thirdly, we mainly focus on classifying faculty home pages. To improve the generalizability of the study, we need to apply the approach to an extended dataset that includes more Web pages and different Web domains. Another future direction of research is to make the classification operating in a dynamic manner. If, for example, after the faculty pages are initially classified by research interests, if a user wants to see the faculty categorized by their teaching interests, the system should quickly be able to regroup the data and present it to the user.

REFERENCES

Attardi, G., A. Gulli, and F. Sebastiani (1999). "Automatic Web Page Categorization by Link and Context Analysis." In C. Hutchison and G. Lanzarone (Eds.), *Proceedings of THAI'99, First European Symposium on Telematics, Hypermedia and Artificial Intelligence*, Varese, IT, 105–119.

Calado, P., M. Cristo, M. A. Goncalves, E. S. de Moura, B. Ribeiro-Neto, and N. Ziviani (2006). "Link-based Similarity Measures for the Classification of Web Documents." *Journal of the American Society for Information Science & Technology* 57(2): 208-221.

Craven, M., D. DiPasquo, D. Freitag, A. McCallum, T. Mitchell, K. Nigam, and S. Slattery (2000). "Learning to Construct Knowledge Bases from the World Wide Web." *Artificial Intelligence* 118(1-2): 69 -113.

Fairthorne, R. A. (1961). *The Mathematics of the Classification: Towards Information Retrieval*. London, Butterwoths.

Fersini, E., E. Messina, and F. Archetti (2008). "Enhancing Web Page Classification through Image-Block Importance Analysis." *Information Processing and Management* 44(4): 1431-1447.

Figuerola, C. G., A. F. Z. Rodriguez, and J. Alonso-Berrocal (2001). "Automatic vs. Manual Categorization of Documents in Spanish." *Journal of Documentation* 57(6): 763-773.

Flake, G. W., S. Lawrence, C. L. Giles, and F. M. Coetzee (2002). "Self-Organization and Identification of Web Communities." *IEEE Computer* 35(3): 66-71.

Foster, I., C. Kesselman, J. Nick, and S. Tuecke (2002). "The Physiology of the Grid: An Open Grid Services Architecture for Distributed Systems Integration." Open Grid Service Infrastructure WG, Global Grid Forum.

GAlib (2005). "GAlib, A C++ Library of Genetic Algorithm Components ." Version 2.4.6 (from http://lancet.mit.edu/ga/; Version 2.4.7 last retrieved on March 15, 2012).

GlobusAlliance (2005). "The Globus Alliance." From http://www.globus.org (last retrieved on March 15, 2012).

Hayes, R. M. (1963). *Mathematical Models in Information Retrieval*. New York, McGraw-Hill.

Holland, J. H. (1975). *Adaptation in Natural and Artificial Systems*. University of Michigan Press.

Kennedy, A. and M. Shepherd (2005). Automatic Identification of Home Pages on the Web. *Proc. Of the 38th Annual Hawaii International Conference on System Science*. Hawaii, USA.

Kousha, K. and M. Thelwall (2007). "How is science cited on the Web? A classification of google unique Web citations." *Journal of the American Society for Information Science & Technology* 58(11): 1631-1644.

Larsen, B. and A. Aone (1999). "Fast and Effective Text Mining Using Linear-time Document Clustering." *Proc. of the Fifth ACM SIGKDD Int'l Conference on Knowledge Discovery and Data Mining*.

Metikurke, S., V. K. Vaishnavi, A. Vandenberg, and L. Li (2006). "Grid-Enabled Automatic Web Page Classification." *Proc. of IEEE World Congress on Computational Intelligence*.

Pathak, P., M. D. Gordonand W. Fan (2000). "Effective Information Retrieval using Genetic Algorithms Based Matching Function Adaptation." *Proc. of the 33rd Hawaii International Conference on System Science (HICSS)*, Hawaii, USA.

Raghavan, V. V. and S. K. M. Wong (1986). "A Critical Analysis of Vector Space Model for Information Retrieval." *Journal of the American Society for Information Science and Technology* 37(5): 279-287.

Salton, G. (1991). "Developments in Automatic text retrieval." *Science* 253: 974-979.

Salton, G., A. Wong, and C. Yang (1975). "A Vector Space Model for Automatic Indexing." *Communications of the ACM* 18(11): 613-620.

Stein, B. and S. M. Z. Eissen (2002). "Document Categorization with Major CLUST." *Proc. Of the 12th Annual Workshop On Information Technologies And Systems (WITS'02)*, Barcelona, Spain.

Tai, X., F. Ren, and K. Kita (2002). "An Information Retrieval Model Based on Vector Space Method by Supervised Learning " *Information Processing and Management* 38(6): 749-764.

Van Rijsbergen, C. (1979). *Information Retrieval.* Butterworth, London.

Wu, Q., S. S. Iyengar, N. S. V. Rao, J. Barhen, V. K. Vaishnavi, H. Qi, and K. Chakrabarty (2004). "On Computing the Route of a Mobile Agent for Data Fusion in a Distributed Sensor Network." *IEEE Transactions on Knowledge and Data Engineering* 16: 740-753.

MEASURING INFORMATION TECHNOLOGY INTERNAL SERVICE QUALITY IN A MANUFACTURING ENVIRONMENT

Michael Braunscheidel, Canisius College
James Hamister, Wright State University
Ann Rensel, Niagara University

ABSTRACT

This paper examines SERVQUAL as a tool for measuring service quality for internal Information Technology support services in a manufacturing environment. Improving internal services and adding voice of the customer measures is an important element in effective Total Quality Management initiatives. SERVQUAL was originally developed for external service quality measurement and therefore requires evaluation for use in the context of internal services. We test two conceptual models of internal service quality with data gathered from a North American manufacturing firm. The first model is based on the gap between expected and perceived service levels. The second model is based on perceptions only. 73 valid responses were received from internal users of IT services. Models were evaluated using structural equation modeling techniques. Our findings suggest that SERVQUAL is a valid instrument for measuring internal service quality in this context, and that there are advantages to adopting a perceptions-only modification to the model.

Keywords: Internal Service Quality, Total Quality Management, SERVQUAL, Structural Equation Modeling, Information Technology Services

INTRODUCTION

An important element of total quality management initiatives is to include the voice of the customer, including internal customers, in quality improvement activities (Deming, 2000). Internal customers are those organizational units or individuals that are serviced by other organizational units. To develop coherent quality control improvement initiatives, those internal suppliers require valid measurement instruments to evaluate the quality of services provided. This paper discusses the evaluation of one such measurement system for information technology (IT) services within a manufacturing organization.

Traditionally the IT/IS function has been a developer and operator of information systems. However, with the advent of the personal computer, the IT function has taken on the additional function of being a service provider. With this additional duty, it is important to be able to measure the quality of the service provided by the IS department. IS departments have

expanded their roles from product developers and operations managers to become service providers (Pitt et al., 1995). The overall quality of the IS department's service, as perceived by its users, is a key indicator of IS success (Moad, 1989). In response to the need to be able to measure the service quality of the IS function, SERVQUAL was adapted by Pitt, Watson & Kavan (1995) to measure the service quality of the IT and IS function.

In organizations that are in the midst of making this transition, the SERVQUAL instrument can provide valuable guidance to the managers and directors of IT. The SERVQUAL instrument will enable these managers to focus on the largest gaps in the services that they provide. Research reports that practitioners find SERVQUAL a useful tool for assessing service quality and determining actions for raising service quality. (Watson, Pitt and Kavan 1998). Kettinger and Lee (1997) state that the SERVQUAL instrument is designed to provide managers with deeper insights concerning the dimensions of IS service quality. Knowledge of these dimensions can provide practitioners with potentially useful diagnostics.

This also ties in very nicely with the notion that one of the purposes of research is to provide practitioners with useful tools. This allows researchers to bridge the gap between the theoretical world and the real world. John P. Campbell, in "The Role of Theory in Industrial and Organizational Psychology (1983)" states "if theory could be improved, then our research and practice would improve commensurately and the enterprise would be the better for it."

LITERATURE REVIEW

One of the fundamental pillars of the Total Quality Management (TQM) initiatives is a strong customer focus, both external and internal. External service quality has been shown to directly increase profit (Spreng and McCoy, 1996) and the importance of viewing employees and internal departments as customers has become evident as well (Davis, 1991). If we consider that each individual employee or department acts as a supplier to others in the organization, then we see that an organization consists of a chain of individuals and departments linked together for the purpose of satisfying the external customers (Bouranta, 2009, Finn et al., 1996). Thus a focus on servicing internal customers is an important part of total quality management initiatives.

There has been substantial work done developing frameworks to evaluate service quality in an external market context (Gronroos, 1984, Kettinger and Lee, 2005) while Berry and Parasuraman (1991) focus on competing through marketing services based upon quality. Much of the work has centered around the SERVQUAL instrument which was originally developed to measure consumer service quality perceptions across a broad spectrum of services (Parasuraman et al., 1988). This tool was developed in response to the increasing trend to use service quality as a differentiator in highly competitive external markets. The focus on measuring service quality in the external market context has continued as has the debate over the effectiveness and use of the SERVQUAL tool (Silvestro, 2005, Buttle, 1996). We will note that there is a very

large literature base discussing the pros and cons of the SERVQUAL tool, thus complete review is beyond the scope of this paper.

The literature on developing valid measures of service for an internal or hierarchical context is less well developed (Brandon-Jones and Silvestro, 2010, Strauss, 1995). Internal customer service has been an important facet of the Total Quality Management (TQM) initiatives because when the internal systems delivering services to the other organizational members and departments is efficient, waste is reduced, costs are decreased, and an improvement in the external service quality will result (Ratcliffe-Smith and Brooks, 1993). There are however, distinct differences between transactions that occur in an external market context that can be distinguished from the more hierarchical internal market transactions. This suggests that any measurement system should be analyzed in a context-specific manner. In an external market, customers have a choice as to trading partners for service transactions (Strauss, 1995) while internal service transactions are generally mandated by management, there are no 'alternative providers' waiting to supply the same service to the internal customer. Under the Transaction Cost Economics (Williamson, 2008) paradigm, internal services are organized to minimize the transaction costs such as search and contracting so the paradigm suggests that activities are handled internally when transaction-specific assets improve efficiency. This is where the nature of internal and external service transactions differs. The presence of external markets creates powerful incentives for quality control and improvement for external transactions since purchasers have alternatives and are generally not obligated to particular suppliers. Internal transactions on the other hand tend to be specified by management through transaction specific-resources with little choice on the part of the customer. Although previous research has shown that focusing on internal service quality impacts external quality (Davis, 1991), quality control and improvement in these circumstances is still driven by managerial actions since market incentives are absent and internal customers have no choice in selecting their service suppliers. From an Information Technology service provision perspective, the IT department is generally responsible for providing services to the internal customers; internal users generally cannot contract with external providers.

Internal transactions also may differ in the sense that there may be significant asset specificity in the codified and tacit knowledge provided by the internal suppliers. If the internal customer is confined to receiving service from the internal supplier because of the unique knowledge or expertise the supplier has, then again the internal customer has no choice in the selection of the service provider (Bruhn, 2003). From an IT department perspective, much of the knowledge pertaining to the organization's systems is very specific. It is the presence of this unique knowledge and expertise that drives managers to organize IT support as an internal department, to supply services to the other organizational members.

From the previous discussion, it is evident that ISQ has been shown to be an important aspect of external service quality, however the environment, or context is somewhat different for evaluating internal service quality compared to external evaluations. In an internal environment,

the market forces that are evident in competitive environment are non-existent. There tends to be a distinct lack of choice available to internal customers, they are confined to using the service suppliers available within the organization regardless of the quality. When considering the service provided by an internal IT department, this situation is can exacerbated by the unique knowledge or expertise that the IT department contains regarding the specific hardware and software that is in use within the organization. This service relationship extends for a long duration, generally because of the expertise and knowledge that the IT department retains.

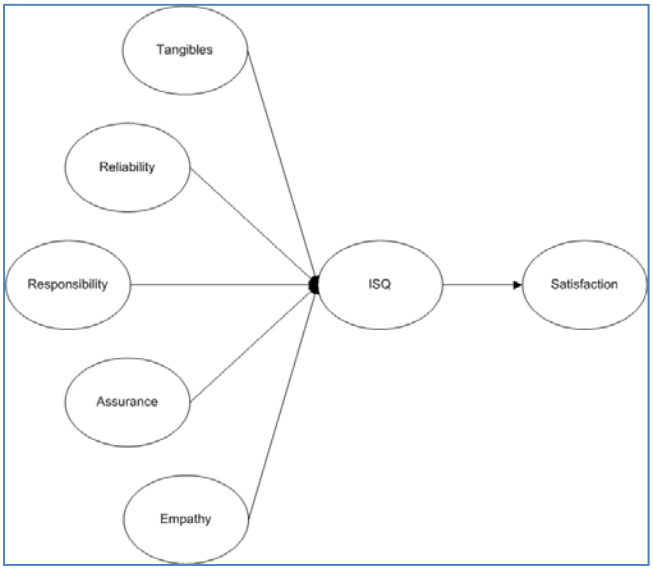
DIMENSIONS OF SERVICE QUALITY

Traditionally, the IT/IS function has been as a developer and operator of the internal organizational information systems. The advent of the personal computer has required that the IT department take on the additional function of being a service provider, with numerous customers throughout the organization. With this additional responsibility, it is important to be able to measure the quality of the service provided by the IT department as they are now a critical part of most modern organizations (Pitt et al., 1995). The overall quality of the IS department's service, as perceived by its users, is a key indicator of IS success (Moad, 1989, Rockart, 1982). In response to the need to be able to measure the service quality of the IS department, SERVQUAL has been adapted and established as an effective tool to measure the service quality of the IT function (Pitt et al., 1995). More recently, a modified SERVQUAL instrument has been used to measure perceived quality of external IT consulting services (Yoon and Suh, 2004). In this work, we return to the use of SERVQUAL as a measure of internal service quality which reflects the overall satisfaction with the IT service group.

The SERVQUAL survey instrument (Pitt et al., 1995, Parasuraman et al., 1988) is a 45-item instrument that measures customers' perceptions and expectations of service quality. It is divided into three parts. The first part contains 22 items that measure the customer's expectations with respect to an excellent provider of the service being studied. The second part (also 22 items) measures the customer's perceptions with respect the current service provider. The last part is a single question regarding the customer's assessment of the overall service quality provided. All questions are measured using a seven (7) point Lickert scale.

There are five (5) dimensions underlying each of the items. They are tangibles (physical facilities, equipment, appearance of personnel), reliability (ability to perform the promised service dependably and accurately), responsiveness (willingness to help customers and provide prompt service), assurance (knowledge and courtesy of employees and their ability to inspire trust and confidence) and empathy (caring, individualized attention the service provider gives its customers). Please see figure 1 for our research model. Service quality for each dimension is captured by a difference score G which represents perceived quality for that item (Pitt, Watson and Kavan 1995).

Figure 1
Research Model



The SERVQUAL survey instrument has been used in the past to evaluate the gaps in service quality in order to provide direction to IT managers (Watson et al., 1998, Pitt et al., 1995, Parasuraman et al., 1988). While there has been and continues to be considerable debate as to the appropriateness of the SERVQUAL survey (Brown et al., 1993, Parasuraman et al., 1993, Kettinger and Choong C. Lee, 1994, Pitt et al., 1995, Teas, 1994, Parasuraman et al., 1994) it has been shown that it is applicable to use for the purposes of providing managers with direction for managing their departments (Watson et al., 1998).

Pitt, Watson & Kavan (1995) caution potential users of SERVQUAL to be aware of its limitations. The reliability of the tangibles construct is low. This is a similar problem with the original instrument but should not be ignored. Also SERVQUAL does not always clearly discriminate among the dimensions of service quality. The dimensions of responsiveness, assurance and empathy are closely aligned concepts and researchers using SERVQUAL to distinguish the impact of service changes should be wary. Its supporters point to the fact that SERVQUAL has many benefits to the real world and this in itself makes it a useful and valuable tool.

GAP VERSUS PERCEIVED QUALITY MODELS

The initial SERVQUAL model bases evaluation of service quality on the gap between expected service quality and perceived service quality. Perceived quality is inherently a subjective judgment of the internal customer and can be differentiated from objective or

engineering viewpoints of service quality. Thus perceived quality can be defined as "a global judgment, or attitude, relating to the superiority of the service (Parasuraman et al., 1988)." Expectations, on the other hand, are the customer's desires or wants. Expected service quality describes the quality level the customer believes the service provider should fulfill. The gap or difference between perceptions and expectations therefore is the basis for consumer evaluation of service quality under this disconfirmation paradigm. Thus the construct internal service quality (ISQ) under this paradigm can be defined as:

ISQ = Perceptions – Expectations (1)

Positive service quality is based on meeting or exceeding expectations, as interpreted by the customer. This expectations gap is evaluated in our research as a difference score between items as described below.

The perceptions expectations gap approach for evaluating quality has received confirmation in the literature (Badri, 2005, Rezazadeh et al., 2011) yet there are several potential problems with this measurement paradigm for evaluating ISQ. First, the use of this measurement tool can imply that one way to improve service quality is to reduce customer expectations. Actions to do so may fit the context of improving measured ISQ, yet these same actions are unlikely to improve overall organization performance. Second, the relationship between the perceptions expectations gap described above and customer satisfaction has been questioned in external service quality research (Cronin Jr. and Taylor, 1992). One recent study of ISQ compared gap-based ISQ measurement to perceptions-based measurement for e-procurement activities (Brandon-Jones and Silvestro, 2010), finding validity in both approaches. It is not clear from that study whether the nature of the service provided influences the appropriate measurement approach. We therefore propose the following research questions.

RQ1 *Is SERVQUAL a valid and reliable measurement instrument of ISQ for IT services in manufacturing?*

RQ2 *Is a perception model preferable to a gap service model for evaluating internal IT service quality?*

METHODS

The following section describes methods employed in evaluating our research questions. First we describe our survey instrument and sampling plan. Next we discuss the use of structural equation modeling (SEM) techniques used in evaluating the two ISQ models described above, the gap model and the perceptions model.

Measurement items were adapted from the SERVQUAL survey instrument (Buttle, 1996). SERVQUAL is a 45-item instrument that measures customers' perceptions and expectations of service quality. It is divided into three parts. The first section (items E01 to

E22) measures the customer's expectations with respect to an excellent provider of the service being studied. The second section (items P01 to P22) measures the customer's perceptions with respect the current service provider. The last part is a single question regarding the customer's assessment of the overall service quality provided. All questions are measured using a seven (7) point Lickert scale, and listed in appendix A.

SAMPLING PLAN

The research question involved assessing internal service quality in an IT context. To that end the researchers enlisted the participation of a North American manufacturing firm to test the proposed satisfaction models. The survey was facilitated by the organization's newly hired CIO who had an interest in measuring ISQ to facilitate service improvement in order to aid an organization-wide transformation in the "way business is done". In the past, the IT department was managed in a very traditional way; i.e. before the advent of personal computers. The view of IT was that of a data provider whose reports were employed by managers to make decisions about the business (Watson et al., 1998, Watson et al., 1993). The transition of IT to a service provider was never made. The new IT management fully realized that IT is very much a service provider and could provide support to the cultural transformation taking place. Since the IT group serves many, if not all of the functions within an organization, employing their services would be a visible sign that change is happening.

SERVQUAL will allow users (customers) of the IT group to assess their perceptions and expectations of IT and communicate them to the IT director. In return SERVQUAL will give the IT director valuable insight into what users expect and perceive and most importantly will then allow him to plan the appropriate strategies and tactics to overcome the existing service quality gaps and address their service perceptions. If implemented properly this will show that management does and will listen to the concerns of the users. This should help to establish a measure of trust, which will be important during the change process.

The sample frame consisted of the users of the company's IT system. This is most appropriate as they are the customers of this service. All departments (accounting, operations, distribution, materials management etc.) were included in the survey distribution. The survey was distributed to the survey population via the company's email system. Recipients were instructed to print a copy, complete the survey and to return it to the corporate human resources department. All survey information was maintained in a strictly confidential manner. The survey was distributed to 184 employees. There were 74 surveys completed and of these 73 were usable. This is an effective response rate of 38.6%. The majority of respondents were employed by the organization for five years or less and worked in a variety of functional areas including distribution, information services, marketing and manufacturing. Most respondents had two or four year college degrees and considered themselves knowledgeable in the use of information systems.

RESULTS

The structural modeling technique Partial Least Squares (Ringle et al., 2005) was employed to evaluate the research questions. This approach has been utilized in a variety of academic disciplines (Sosik et al., 2009) including strategic management (Mezner and Nigh, 1995, Birkinshaw et al., 1995, Hulland, 1999), and management information systems (Chin and Gopal, 1995, Chin and Newsted, 1995, Majchrzak et al., 2005). PLS is a structural equation modeling technique that relies on ordinary least squares methods as opposed to a covariance based methods as employed by other SEM techniques such a LISREL and AMOS (Gefen et al., 2000, Chin et al., 2003). PLS is suited for explaining complex relationships (Fornell and Bookstein, 1982, Fornell et al., 1990) and prediction (Anderson and Gerbing, 1988). PLS is less prescriptive on measurement properties than are covariance-based methods (Sosik et al., 2009, Faulk and Miller, 1992). The components-based approach to SEM is preferred for small sample research. Sample size requirements for PLS are ten (10) times the larger of the following (a) the block with the largest number of formative indicators or (b) the dependent latent variable with the largest number of independent latent variables impacting it (Chin, 1998b), which suggests a minimum sample size of 50 for this research.

The structural and measurement models under PLS consist of three (3) sets of relations: the inner model which specifies the relationships between latent variables, the outer model which specifies the relationships between the latent variables and their associated observed variables and the weight relations upon which the case values for the latent variables can be estimated (Chin, 1998b). Model fit is established with significant path coefficients, acceptably high R^2 and internal consistency (construct reliability) above .70 for each construct (Gefen et al., 2000). The overall fit of structural equation models using PLS are evaluated by examining the R^2 for dependent constructs. In addition, the structural paths are measured by path weights and t-statistics similar to the way that beta weights are interpreted in linear regression (Gefen et al., 2000, Chin, 1998a).

MEASUREMENT MODELS

The measurement models are analyzed prior to assessing the structural models to assure that structural relationships are analyzed based on valid and reliable measures (Anderson and Gerbing, 1992). Reliability is the ability of a scale to consistently yield the same response under the same conditions. Three different methods were used to assess reliability. First Cronbach's alpha, a popular measure of internal consistency, was calculated. A minimum value of 0.70 is considered acceptable for existing scales (Nunnally, 1978). Chin (2010b) points out that alpha is a lower-bound estimate for reliability since all indicators are equally weighted in alpha, but differentially weighted in the measurement model. Two other measures of reliability are

therefore also recommended: composite reliability (CR) with a lower bound of 0.70 and average variance extracted (AVE) which has a suggested lower value equal to 0.50. Tables 1 and 2 provide details with respect to reliability and validity of both the gap and the perceptions model. All measured constructs exhibit acceptable reliability based on the standard employed.

TABLE 1
RELIABILITY GAP MODEL

Scale	**Cronbach's Alpha Min >= 0.70**	**Composite Reliability Min >= 0.70**	**Average Variance Extracted Min >= 0.50**
GapTangibles	.79	.84	.58
GapReliable	.94	.96	.81
GapResponsive	.91	.94	.78
GapAssurance	.90	.93	.77
GapEmpathy	.90	.93	.78

TABLE 2
RELIABILITY PERCEIVED MODEL

Scale	**Cronbach's Alpha Min >= 0.70**	**Composite Reliability Min >= 0.70**	**Average Variance Extracted Min >= 0.50**
TANGIBLE	.77	.85	.58
RELIABLE	.91	.94	.75
RESPONSIVE	.87	.91	.73
ASSURANCE	.88	.92	.74
EMPATHY	.89	.92	.75

Convergent validity, the extent to which items measure the same construct, was evaluated through a review of item loadings to the construct of interest in the measurement model. Standardized loadings generally should be greater than .70 for established measures. Please see tables 3 and 4 for all item loadings and crossloadings for the gap and perceived models respectively. Item P19 was removed from measurement of the perceived empathy construct due to poor loading, as well as item G19 from the empathy gap model for the same reason. It should be noted that item crossloadings are fairly high in both measurement models, which suggests that discriminant validity is not high in either model (Rosenthal and Rosnow, 1991). Items load higher on their defined scale than on other scales in the study. Some crossloading is expected in the measurement model due to the structural relationship between constructs.

TABLE 3: Gap ModelItem Loading and Crossloading							
MV	*Mean*	*Std. Dev.*	*GapAssurance*	*GapEmpathy*	*GapReliability*	*GapResponsiveness*	*GapTangibles*
G01	-1.14	2.43	0.51	0.56	0.57	0.59	**0.87**
G02	-0.41	1.59	0.26	0.29	0.08	0.22	**0.69**
G03	-0.31	1.66	0.11	0.15	0.11	0.10	**0.63**
G04	-0.32	1.65	0.26	0.31	0.19	0.28	**0.83**
G05	-2.25	2.21	0.61	0.65	**0.93**	0.79	0.41
G06	-1.99	2.01	0.70	0.73	**0.92**	0.81	0.31
G07	-2.17	2.09	0.64	0.71	**0.91**	0.79	0.30
G08	-2.36	2.14	0.67	0.67	**0.94**	0.81	0.42
G09	-1.55	1.87	0.68	0.64	**0.80**	0.68	0.42
G10	-2.00	2.10	0.71	0.71	0.80	**0.85**	0.62
G11	-2.44	2.14	0.76	0.77	0.81	**0.93**	0.46
G12	-2.01	2.04	0.81	0.81	0.76	**0.91**	0.34
G13	-2.10	2.14	0.76	0.79	0.68	**0.84**	0.29
G14	-1.61	2.16	**0.91**	0.72	0.67	0.78	0.43
G15	-1.62	1.76	**0.91**	0.71	0.64	0.76	0.41
G16	-1.36	1.83	**0.88**	0.79	0.64	0.74	0.34
G17	-1.61	1.60	**0.81**	0.70	0.62	0.74	0.37
G18	-1.31	1.75	0.81	**0.89**	0.70	0.81	0.50
G20	-1.03	1.69	0.62	**0.84**	0.56	0.69	0.47
G21	-1.65	1.77	0.77	**0.91**	0.67	0.79	0.38
G22	-2.01	1.97	0.72	**0.89**	0.71	0.76	0.42

TABLE 4: Perceived Model Item Loading and Crossloading							
Variable	*Mean*	*Std. Dev.*	*Assurance*	*Empathy*	*Reliable*	*Responsive*	*Tangible*
P1	4.22	1.47	0.39	0.41	0.40	0.40	**0.76**
P2	4.26	1.19	0.27	0.19	0.12	0.20	**0.72**
P3	4.61	1.31	0.40	0.28	0.26	0.27	**0.72**
P4	4.57	1.18	0.34	0.28	0.21	0.24	**0.85**
P5	3.51	1.64	0.52	0.64	**0.91**	0.76	0.35
P6	4.00	1.68	0.63	0.69	**0.89**	0.77	0.26
P7	3.85	1.61	0.58	0.70	**0.89**	0.75	0.28
P8	3.51	1.61	0.58	0.65	**0.94**	0.76	0.31
P9	4.15	1.37	0.51	0.48	**0.69**	0.59	0.33
P10	3.63	1.61	0.58	0.60	0.69	**0.80**	0.42
P11	3.40	1.67	0.71	0.73	0.80	**0.92**	0.40
P12	4.03	1.63	0.78	0.75	0.69	**0.86**	0.33
P13	3.35	1.58	0.67	0.72	0.68	**0.82**	0.14
P14	4.11	1.52	**0.90**	0.72	0.66	0.78	0.47
P15	4.38	1.49	**0.88**	0.69	0.54	0.70	0.43
P16	4.75	1.57	**0.85**	0.68	0.53	0.63	0.35
P17	4.81	1.39	**0.81**	0.71	0.50	0.66	0.36
P18	4.40	1.59	0.75	**0.89**	0.67	0.75	0.35
P20	4.58	1.62	0.55	**0.81**	0.60	0.61	0.29
P21	4.15	1.54	0.78	**0.86**	0.59	0.72	0.33
P22	3.82	1.64	0.72	**0.90**	0.69	0.77	0.42

Discriminant validity is also analyzed by comparing the square root of AVE to the correlation among latent variables. This establishes that the more variation is shared between latent variables and their indicators than is shared between latent variables (Fornell and Larker, 1981). Tables 5 and 6 show the square root of AVE along the diagonal, and LV correlations in the matrix. Note that constructs are highly correlated in both models.

Table 5
Gap Model Discriminant Validity

	GapAssurance	GapEmpathy	GapReliable	GapResponsive	GapTangible
GapAssurance	**.88**				
GapEmpathy	.83	**.88**			
GapReliable	.73	.75	**.90**		
GapResponsive	.85	.87	.86	**.89**	
GapTangible	.49	.51	.41	.49	**.76**

Table 6
Perceived Model Discriminant Validity

	Assurance	Empathy	Reliable	Responsive	Tangible
Assurance	**.86**				
Empathy	.81	**.88**			
Reliable	.65	.74	**.87**		
Responsive	.81	.83	.84	**.85**	
Tangible	.47	.41	.35	.39	**.76**

STRUCTURAL MODELS

The structural models are evaluated using structural modeling techniques evaluated with the partial least squares (PLS) algorithm using SmartPLS software version 2.0 (Ringle et al., 2005). Structural parameter variances were estimated by bootstrapping (Chin, 2010a). The structural model for the gap satisfaction model is presented in figure 2. Variation in the second-order construct GapISQ is associated with 36% of the variation in the single-measure item that rated overall service quality (item S1). All path coefficients are statistically significant at an alpha .05 level based on bootstrapping estimates of parameter variance. The highest contribution to GapISQ is in GapReliability (β = .30, $p<.01$), with the smallest contribution from GapTangibles (β = .10, $p < .05$).

The structural model for the perceived satisfaction model is presented in figure 3. Path coefficients between the latent variables and ISQ ranged from 0.10 for Tangibles to 0.31 for Reliable. The second-order factor ISQ is associated with 71% of the variation in the single-measure item that rated overall service quality (item S1). All path coefficients in the structural model are statistically significant at the alpha .05 level. The highest contribution to ISQ is in Reliability (β = .31, $p < .05$), with the smallest contribution from Tangibles (β = .10, $p < .01$).

Figure 2
Gap Model

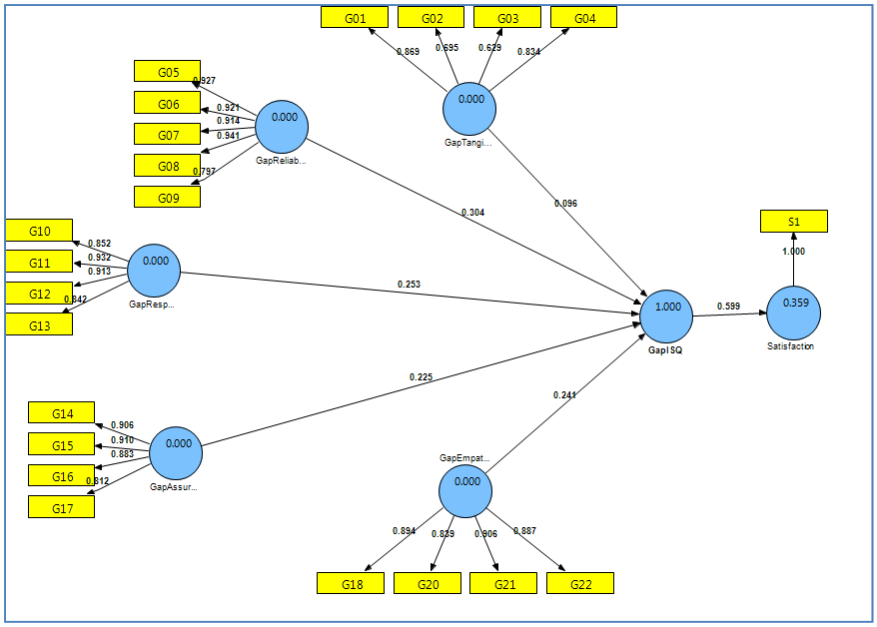
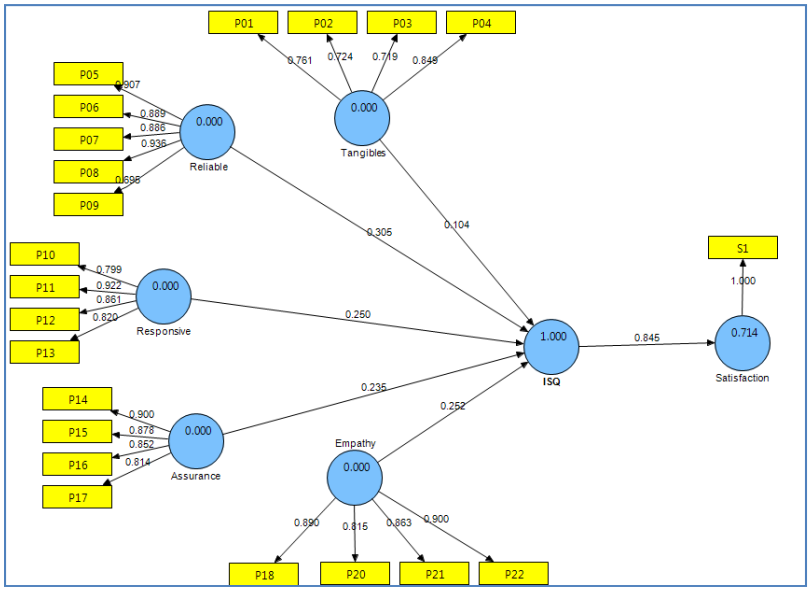


Figure 3
Perceived Satisfaction Model



DISCUSSION

Our first research question involved analyzing the validity of SERVQUAL in its original conception as a gap model for measuring ISQ for internal IT services. The measurement items demonstrated acceptable reliability and statistical validity in measuring ISQ when adjusted as described above. Item 19 was removed in measuring the Empathy construct for reasons of poor convergent validity. It's likely that this measurement items are interpreted differently in an ISQ context than they are for the external service quality measurement which is the original design intent of SERVQUAL. Item 19 refers to convenient operating hours. The organization that we studied operates domestically with traditional office hours for both internal customers and service providers. Thus operating hours are likely to be irrelevant for interpreting ISQ in this context. This item may be relevant in an ISQ context where there are multiple time zones and service availability unavailability during expected working hours. The gap model explains a medium amount of variation (Cohen, 1992) in the overall satisfaction measure, thus SERVQUAL exhibits acceptable measurement properties in an ISQ context thus can be an acceptable instrument for these purposes.

Evaluation of internal customer response patterns suggests several opportunities for improvement for the example company. First we note that expected service levels exceed perceived service levels on average, based on the negative values reported in Table 7. Internal customer expectations are not being met at this organization. The largest gaps between perceptions and expectations are with Responsiveness and Reliability. Managerial actions that address these gaps will improve ISQ and therefore user satisfaction. These actions can include design activities such as worker training and increased capacity to reduce service wait times. The perceptions/expectations gap can also be improved by reducing internal customer expectations. Reducing expectations may involve a more realistic communications of IT Services capabilities so that internal customer expected service levels are better aligned with current capabilities. In fact, underselling capabilities will improve satisfaction based on this model. Actions that reduce this gap through lowered expectations may not increase service performance in an absolute sense, but are consistent with improving performance under the gap model.

In comparing the perceptions only model to the gap model, we find that the perceptions only model explains 71% of the variation in the customer satisfaction dependent variable versus 36% in the gap model. The pattern of relationships between the dimensions of service quality and the second-order construct ISQ are fairly consistent between both models. Thus regardless of the model employed, direction that can be provided to the IT Director is consistent in terms of which dimensions of ISQ need organizational improvement. Both models suggest that improving the tangible features will have the least impact on ISQ, while improving reliability will have the greatest impact. While the SERVQUAL model has been validated in past literature (Buttle, 1996) it has also been noted that there is a high degree of co-linearity among the various

constructs that comprise the SERVQUAL model. While somewhat problematic from a statistical point of view, from a managerial viewpoint of view this can have important implications. To illustrate this point, consider the fact that empathy and assurance are highly correlated at 0.81. Thus activities that improve perceived empathy are also likely to improve assurance, thus improving customer satisfaction.

The perceived model has several advantages for practical measurement of ISQ in this context. First, measurement properties are valid and reliable as established above, explaining more variation in the satisfaction measure than did the gap model. Second, the perceived model is simpler to administer in practice due to fewer overall measurement items. Smaller surveys can improve participation rates and increase the attentiveness of the respondent (Dillman, 2000). Third, the perceived model interpretation is more transparent than is the gap model, since the gap construct represents a difference score between two separate constructs and may be difficult to interpret for managers. Fourth, managerial actions to improve performance are more consistent with quality improvement philosophy as described above. Thus we argue for this context that using SERVQUAL measurement items with the perceived model is preferred in this context.

CONCLUSIONS, IMPLICATIONS AND LIMITATIONS

The objective of this research project was to evaluate the use of the SERVQUAL instrument to assess service quality for internal IT services. The SERVQUAL instrument was originally developed for evaluating services in an external environment (Buttle, 1996), and there are important differences between internal and external services that must be considered prior to adopting this measurement system. Our second objective was to determine whether a perceptions based model is preferred to the gap-based model of the original SERVQUAL design. We found that in the case of a North American manufacturing firm, SERVQUAL can serve as an effective measurement instrument for internal service quality, and identify important areas of improvement for the internal service provider. We also identify several advantages of using the perceptions-based model in this context. First, the perceptions-only model of ISQ is better aligned with overall reported satisfaction, explaining 71% of variation versus 36% of variation for the gap model. In addition, the perceptions-only model may be better aligned philosophically with improvement activities associated with effective TQM initiatives.

There are several limitations in this research that should be considered when evaluating these results. First, our sampling plan was limited to single firm. This decision helped to improve internal validity to our findings by eliminating confounding effects that may occur when evaluating multiple firms, and kept our research budget to a reasonable level. A multiple-firm sampling plan is proposed for future research to better establish external validity of our finding. A second limitation is that we limited our pool of items to those in the SERVQUAL inventory. There are a broader range of items available in the literature (see Brandon-Jones and Silvestro

(2010) for example) that could be evaluated in the internal IT context to potentially improve ISQ measurement precision.

REFERENCES

Anderson, J. C. & Gerbing, D. W. (1988) Structural equation modeling in practice: A review and recommended two-step approach. *Psychological Bulletin,* 103**,** 411-423.

Anderson, J. C. & Gerbing, D. W. (1992) Assumptions and comparative strengths of the two-step approach. *Sociological Methods & Research,* 20**,** 321-333.

Badri, M. A. A., Mohamed; Al-Madani, Abdelwahab (2005) Information technology center service quality: Assessment and application of servqual. *The International Journal of Quality and Reliability Management,* 22**,** 819-848.

Berry, L. L. & Parasuraman, A. (1991) *Marketing services: Competing through quality,* New York, The Free Press.

Birkinshaw, J., Morrison, A. & Hulland, J. (1995) Structural and competitive determinants of a global integration strategy. *Strategic Management Journal,* 16**,** 637-655.

Bouranta, N. C., Leonidas; Paravantis, John (2009) The relationship between internal and external service quality. *International Journal of Contemporary Hospitality Management,* 21**,** 275-293.

Brandon-Jones, A. & Silvestro, R. (2010) Measuring internal service quality: Comparing the gap-based and perceptions-only approaches. *International Journal of Operations & Production Management,* 30**,** 1291-1318.

Brown, T. J., Churchill Jr, G. A. & Peter, J. P. (1993) Research note: Improving the measurement of service quality. *Journal of Retailing,* 69**,** 127.

Bruhn, M. (2003) Internal service barometers. *European Journal of Marketing,* 37**,** 1187-1204.

Buttle, F. (1996) Servqual: Review, critique, research agenda. *European Journal of Marketing,* 30**,** 8.

Campbell, J. P. (1983) The role of theory in industrial and organizational psychology. IN Dunnette, M. D. & Hough, L. M. (Eds.) *Handbook of industrial and organizational psychology.* Consulting Psychologists Press, Inc.

Chin, W. W. (1998a) Issues and opinion on structural equation modeling. *MIS Quarterly,* 22.

Chin, W. W. (1998b) Partial least squares approach to structural equation modeling. IN Marcoulides, G. A. (Ed.) *Modern methods for business research.* Mahwah, New Jersey, Lawrence Erlbaum Associates.

Chin, W. W. (2010a) Bootstrap cross-validation indices for pls path model assessment. IN Vinzi, V. E., Chin, W. W., Henseler, J. & Wang, H. (Eds.) *Handbook of partial least squares.* Berlin, Springer-Verlag.

Chin, W. W. (2010b) How to write up and report pls analyses. *Handbook of partial least squares: Concepts, methods and applications.* Springer.

Chin, W. W. & Gopal, A. (1995) Adoption intention in gss: Relative imporatnce of beliefs. *DATA BASE Advances,* 26**,** 42-64.

Chin, W. W., Marcolin, B. L. & Newsted, P. R. (2003) A partial least squares latent variable modeling approach for measuring interaction effects: Results from a monte carlo simulation study and voice mail emotion/adoption study. *Information Systems Research,* 14**,** 189-217.

Chin, W. W. & Newsted, P. R. (1995) The importance of specification in causal modeling: The case of end-user computing satisfaction. *Information Systems Research,* 6**,** 73-81.

Cohen, J. (1992) A power primer. *Psychological Bulletin,* 112**,** 155-159.

Cronin Jr., J. J. & Taylor, S. A. (1992) Measuring service quality: A reexamination and extension. *Journal of Marketing,* 56**,** 55-68.

Davis, T. R. (1991) Internal service operations: Strategies for increasing their effectivness and controlling their cost. *Organizational Dynamics,* 2-**,** 5-23.

Deming, W. E. (2000) *Out of the crisis: Quality, productivity and competitive position,* Cambridge, MA, The MIT Press.

Dillman, D. A. (2000) *Mail and internet surveys: The tailored design method,* New York, John Wiley & Sons, Inc.

Faulk, R. F. & Miller, N. B. (1992) *A primer for soft modeling,* Akron, OH, University of Akron Press.

Finn, D. W., Baker, J., Marshall, G. W. & Anderson, R. (1996) Total quality management and internal customer: Measuring internal service quality. *Journal of Marketing Theory and Practice,* 4**,** 63-70.

Fornell, C. & Bookstein, F. L. (1982) Two structural equation models: Liseral and pls applied to consumer exit-voice theory. *Journal of Marketing Research,* 19**,** 440-452.

Fornell, C. & Larker, D. F. (1981) Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research,* 18**,** 39-50.

Fornell, C., Lorange, P. & Roos, J. (1990) The cooperative venture formation process: A latent variable structural modeling approach. *Management Science,* 36**,** 1246-1255.

Gefen, D., Straub, D. W. & Boudreau, M. (2000) Structural equation modeling and regression: Guidelines for research practice. *Commuinications of the Association for Information Systems,* 4.

Gronroos, C. (1984) A service quality model and its market implications. *European Journal of Marketing,* 18**,** 36-44.

Hulland, J. (1999) Use of partial least square (pls) in strategic management research: A review of four recent studies. *Strategic Management Journal,* 20**,** 195-204.

Kettinger, W. J. & Choong C. Lee, W. J. (1994) Perceived service quality and user satisfaction with the information services function. *Decision Sciences,* 25**,** 737-766.

Kettinger, W. J. & Lee, C. C. (1997) Pragmatic perspectives on the measurement of information systems service quality. *MIS Quarterly,* 21**,** 223-240.

Kettinger, W. J. & Lee, C. C. (2005) Zones of tolerance; alternative scales for measuring information systems service quality. *MIS Quarterly,* 29**,** 607-622.

Majchrzak, A., Beath, C., Lim, R. & Chin, W. (2005) Managing client dialogues during information systems design to facilitate client learning. *MIS Quarterly,* 29**,** 653-672.

Mezner, M. B. & Nigh, D. (1995) Buffer or bridge? Environmental and organizational determinants of public affairs activities in american firms. *Academy of Management Journal,* 38**,** 975-996.

Moad, J. (1989) Asking users to judge is. *Datamation,* 35**,** 93.

Nunnally, J. C. (1978) *Psychometric theory,* New York, NY, McGraw-Hill.

Parasuraman, A., Berry, L. L. & Zeithaml, V. A. (1993) Research note: More on improving service quality measurement. *Journal of Retailing,* 69**,** 140.

Parasuraman, A., Zeithaml, V. A. & Berry, L. L. (1988) Servqual: A multiple-item scale for measuring consumer perceptions of service quality. *Journal of Retailing,* 64**,** 12-40.

Parasuraman, A., Zeithaml, V. A. & Berry, L. L. (1994) Reassessment of expectations as a comparison standard in measuring service quality: Implications for further research. *Journal of Marketing,* 58**,** 111-124.

Pitt, L. Y. F., Watson, R. T. & Kavan, C. B. (1995) Service quality: A measure of information systems effectiveness. *MIS Quarterly,* 19**,** 173-187.

Ratcliffe-Smith, J. & Brooks, R. (1993) Service from within. *TQM Magazine,* 5**,** 41-43.

Rezazadeh, M. V., Yaghoubi, N.-M. & Nikoofar, M. (2011) Review of sport service quality by servqual model (a case study). *Interdisciplinary Journal of Contemporary Research in Business,* 12**,** 173-181.

Ringle, C. M., Wende, S. & Will, A. (2005) Smartpls. 2.0 ed. Hamburg, Germany, SmartPLS.

Rockart, J. F. (1982) The changing role of the information systems executive: A critical success factors perspective. *Sloan Management Review,* 24**,** 3-13.

Rosenthal, R. & Rosnow, R. L. (1991) *Essentials of behavioral research methods and data analysis,* Boston, MA, McGraw Hill.

Silvestro, R. (2005) Applying gap analysis in the health service to inform the service improvement agenda. *The International Journal of Quality & Reliability Management,* 22**,** 215-233.

Sosik, J. J., Kahai, S. S. & Piovoso, M. J. (2009) Silver bullet or voodoo statistics?: A primer for using the partial least squares data analytic technique in group and organizational research. *Group Organization Management,* 34**,** 5-36.

Spreng, R. A. & Mccoy, R. D. (1996) An empirical examiniation of a model of perceived service quality and satisfaction. *Journal of Retailing,* 72**,** 201-214.

Strauss, B. (1995) Internal services: Classification and quality management. *Journal of Service Management,* 6**,** 62-78.

Teas, R. K. (1994) Expectations as a comparison standard in measuring service quality: An assessment of a reassessment. *Journal of Marketing,* 58**,** 132-139.

Watson, R. T., Pitt, L. F., Cunningham, C. & Nel, D. (1993) User satisfaction and service quality of the is department: Closing the gaps. *Journal of Information Technology,* 8**,** 257-266.

Watson, R. T., Pitt, L. F. & Kavan, C. B. (1998) Measuring information systems service quality: Lessons from two longitudinal case studies. *MIS Quarterly,* 22**,** 61-79.

Williamson, O. E. (2008) Outsourcing: Transaction cost economics and supply chain management. *Journal of Supply Chain Management,* 44**,** 5-16.

Yoon, S. & Suh, H. (2004) Ensuring it consulting servqual and user satisfaction: A modified measurement tool. *Information Systems Frontiers,* 6**,** 341-351.

APPENDIX I

Service Quality Expectations (*of an excellent provider of IS service*)

Directions: This survey deals with your opinion of the Information Systems Department (IS). Based on your experiences as a user, please think about the kind of IS unit that would deliver excellent quality of service. Think about the kind of IS unit with which you would be pleased to do business. Please show the extent to which you think such a unit would possess the feature described by each statement. If you strongly agree that these units should possess a feature, circle 7. If you strongly disagree that these units should possess a feature, circle 1. If your feeling is less strong, circle one of the numbers in the middle. There are no right or wrong answers-all we are interested in is a number that truly reflects your expectations about IS.

Please respond to ALL the statements	Strongly Disagree — Neutral — Strongly Agree
1 They will have up-to-date hardware and software	1 ------ 2 ------3 ----- **4** ----- 5 ----- 6 ----- 7
2 Their physical facilities will be visually appealing	1 ------ 2 ------3 ----- **4** ----- 5 ----- 6 ----- 7
3 Their employees will be well dressed and neat in appearance	1 ------ 2 ------3 ----- **4** ----- 5 ----- 6 ----- 7
4 The appearance of the physical facilities of these IS units will be in keeping with the kind of services provided	1 ------ 2 ------3 ----- **4** ----- 5 ----- 6 ----- 7
5 When these IS units promise to do something by a certain time, they will do so	1 ------ 2 ------3 ----- **4** ----- 5 ----- 6 ----- 7

	Strongly Disagree — Neutral — Strongly Agree
6 When users have a problem, these IS units will show a sincere interest in solving it	1 ------ 2 ------3 ----- **4** ----- 5 ----- 6 ----- 7
7 These IS units will be dependable	1 ------ 2 ------3 ----- **4** ----- 5 ----- 6 ----- 7
8 They will provide their services at the times they promise to do so	1 ------ 2 ------3 ----- **4** ----- 5 ----- 6 ----- 7
9 They will insist on error-free records	1 ------ 2 ------3 ----- **4** ----- 5 ----- 6 ----- 7
10 They will tell users exactly when services will be performed	1 ------ 2 ------3 ----- **4** ----- 5 ----- 6 ----- 7
11 Employees will give prompt service to users	1 ------ 2 ------3 ----- **4** ----- 5 ----- 6 ----- 7
	1 ------ 2 ------3 ----- **4** ----- 5 ----- 6 ----- 7

12 Employees will always be willing to help users

13 Employees will never be too busy to respond to users' requests 1 ------ 2 ------3 ----- **4** ----- 5 ----- 6 ----- 7

14 The behavior of employees will instill confidence in users 1 ------ 2 ------3 ----- **4** ----- 5 ----- 6 ----- 7

15 Users will feel safe in their transactions with these IS units' employees 1 ------ 2 ------3 ----- **4** ----- 5 ----- 6 ----- 7

16 Employees will be consistently courteous with users 1 ------ 2 ------3 ----- **4** ----- 5 ----- 6 ----- 7

17 Employees will have the knowledge to do their job well 1 ------ 2 ------3 ----- **4** ----- 5 ----- 6 ----- 7

18 These IS units will give users individual attention 1 ------ 2 ------3 ----- **4** ----- 5 ----- 6 ----- 7

19 These IS units will have operating hours convenient to all their users 1 ------ 2 ------3 ----- **4** ----- 5 ----- 6 ----- 7

20 These IS units will have employees who give users personal attention 1 ------ 2 ------3 ----- **4** ----- 5 ----- 6 ----- 7

21 These IS units will have the users' best interests at heart 1 ------ 2 ------3 ----- **4** ----- 5 ----- 6 ----- 7

22 The employees of these IS units will understand the specific needs of their users 1 ------ 2 ------3 ----- **4** ----- 5 ----- 6 ----- 7

Service Quality Perceptions (*of the service provided by IS department*)

Directions: The following set of statements relate to your feelings about _____ IS unit. For each statement, please show the extent to which you believe _____ IS has the feature described by the statement. Once again, circling a 7 means that you strongly agree that _____ IS has that feature, and circling 1 means that you strongly disagree. You may circle any of the numbers in the middle that show how strong your feelings are. There are no right or wrong answers-all we are interested in is a number that best shows your perceptions about _____ IS unit.

	Strongly Disagree	Neutral	Strongly Agree
Please respond to ALL the statements.			
1 IS has up-to-date hardware and software	1 ------ 2 ------3 ----- **4** ----- 5 ----- 6 ----- 7		
2 IS's physical facilities are visually appealing	1 ------ 2 ------3 ----- **4** ----- 5 ----- 6 ----- 7		
	1 ------ 2 ------3 ----- **4** ----- 5 ----- 6 ----- 7		

3 IS's employees are well dressed and neat in appearance	
4 The appearance of the physical facilities of IS is in keeping with the kind of services provided	1 ------ 2 ------3 ----- **4** ----- 5 ----- 6 ----- 7
5 When IS promises to do something by a certain time, it does so	1 ------ 2 ------3 ----- **4** ----- 5 ----- 6 ----- 7
6 When users have a problem, IS shows a sincere interest in solving it	1 ------ 2 ------3 ----- **4** ----- 5 ----- 6 ----- 7
7 IS is dependable	1 ------ 2 ------3 ----- **4** ----- 5 ----- 6 ----- 7
8 IS provides its services at the times it promises to do so	1 ------ 2 ------3 ----- **4** ----- 5 ----- 6 ----- 7
9 IS insists on error-free records	1 ------ 2 ------3 ----- **4** ----- 5 ----- 6 ----- 7
10 IS tell users exactly when services will be performed	1 ------ 2 ------3 ----- **4** ----- 5 ----- 6 ----- 7
11 IS employees give prompt service to users	1 ------ 2 ------3 ----- **4** ----- 5 ----- 6 ----- 7
12 IS employees are always willing to help users	1 ------ 2 ------3 ----- **4** ----- 5 ----- 6 ----- 7
13 IS employees are never too busy to respond to users' requests	1 ------ 2 ------3 ----- **4** ----- 5 ----- 6 ----- 7
	y
	Disagree Agree
14 The behavior of IS employees instills confidence in users	1 ------ 2 ------3 ----- **4** ----- 5 ----- 6 ----- 7
15 Users will feel safe in their transactions with IS's employees	1 ------ 2 ------3 ----- **4** ----- 5 ----- 6 ----- 7
16 IS employees are consistently courteous with users	1 ------ 2 ------3 ----- **4** ----- 5 ----- 6 ----- 7
17 IS employees have the knowledge to do their job well	1 ------ 2 ------3 ----- **4** ----- 5 ----- 6 ----- 7
18 IS gives users individual attention	1 ------ 2 ------3 ----- **4** ----- 5 ----- 6 ----- 7
19 IS has operating hours convenient to all its users	1 ------ 2 ------3 ----- **4** ----- 5 ----- 6 ----- 7
	1 ------ 2 ------3 ----- **4** ----- 5 ----- 6 ----- 7

20 IS has employees who give users personal attention.

21 IS has the users' best interests at heart 1 ------ 2 ------ 3 ------ **4** ------ 5 ------ 6 ------ 7

22 Employees of IS understand the specific needs of its users 1 ------ 2 ------ 3 ------ **4** ------ 5 ------ 6 ------ 7