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LETTER FROM THE EDITORS

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UNDERSTANDING THE RELATIONSHIP BETWEEN UNCERTAINTY AND INTERNATIONAL INFORMATION TECHNOLOGY SOURCING STRATEGY: A CONCEPTUAL FRAMEWORK

Mujtaba Ahsan, Pittsburg State University
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ABSTRACT

Drawing on organizational learning and real options literature, we examine how uncertainty affects a client's international information technology (IT) sourcing (offshoring) strategy. Distinguishing between endogenous and exogenous uncertainty, we introduce a two-dimensional framework to further our understanding of uncertainty and highlight the role that uncertainty plays on the firm's international IT sourcing decision. We take an expanded view of uncertainty and provide insight into how a client firm's IT offshoring strategy may be directed by the various uncertainties encountered. Based on the existing literature and our analysis, a number of propositions are presented to guide future IT offshoring uncertainty research.

INTRODUCTION

The inherent economic advantages of international offshore sourcing (offshoring) work to cheaper offshore locations have made offshoring a business necessity for many enterprises. More and more organizations are relying on offshoring to provide critical information technology (IT) products and services and this phenomenon is likely to continue into the future (Davis, Ein-Dor, King & Torkzadeh, 2006). Significant cost savings are not the only or major objective for IT offshoring. Many companies are forced to offshore due to the lack of available technical talent in their home country (Ernst, 2006). However, the decision to offshore involves a certain degree of uncertainty for the firm (client) entering the offshoring arena. The question is not always about whether it is better for a company to insource or outsource. Rather, the question is increasingly becoming – how can companies reduce the uncertainties associated with IT offshoring and fit their IT offshoring strategies to the uncertainties encountered? To date, there has been little research investigating how IT managers address and match uncertainty with their IT offshoring strategy.

Much has been written about the management of and the decision to adopt IT outsourcing and offshoring (i.e., Lacity & Willcocks, 1996; Wang, 2002). Generally, when examining the IT

outsourcing decision, the literature has focused on costs and control structures (Kern & Willcocks, 2000; Kim & Kim, 2008). Relatively few studies have investigated the uncertainties that surround the IT offshoring decision (i.e., Saunders, Gebelt & Hu, 1997). This is somewhat surprising given that nearly all international investments, including IT offshoring, are impacted by uncertainty and dealing with this uncertainty is crucial for success. Recent research by Hahn, Doh and Bunyaratevej (2009) suggests a significant need to examine the determinants of firm IT offshoring behavior with respect to offshoring location risk.

Given the predicted growth of the offshoring phenomenon, and the significant role of risk with a firm's performance, there is ample opportunity and an essential need for academics and practitioners to understand the impact of uncertainties in regards to the IT offshoring decision. Previous research has failed to fully capture and explain the role of uncertainties involved in IT offshoring. A framework that would synthesize the role of uncertainty in the context of the IT offshoring decision has yet to fully emerge. Moreover, much of the existing research on offshoring has assumed that the different forms of uncertainties (i.e., political uncertainty, cultural uncertainty, macroeconomic uncertainty, etc.) have the same (or similar) effect on a client firm's offshoring decision (i.e., Aspray, Mayadas & Vardi, 2006; Hahn et al., 2009; Kleim, 2004). We argue that this not true as some uncertainties can only be resolved through learning (i.e., a client firm's activities) and other uncertainties evolve independent of a client firm's activities. Drawing on the real options and organization learning theories we develop a framework that incorporates uncertainty in explaining the IT offshoring model decision. To parsimoniously assess the uncertainty inherent to IT offshoring our proposed framework distinguishes between endogenous and exogenous uncertainties in relation to the IT offshoring decision. Specifically, we argue the level of endogenous and exogenous uncertainty surrounding IT offshoring determines whether a client firm adopts a captive offshoring, joint-venture, third-party or onsite IT offshoring model. In doing so, we seek to fill an important gap in the IT offshoring literature.

The remainder of the paper is organized as follows. The next section reviews the extant IT offshoring literature in regards to uncertainty. Next, we develop a theoretical framework used to examine uncertainty in the IT offshoring environment. The third section discusses the propositions regarding the role of uncertainty and the IT offshoring decision. We then present an illustrative case example demonstrating how our framework captures the evolution of a client firm's IT offshoring strategy to fit the uncertainties faced by the client firm. We conclude with sections presenting the research limitations, suggest implications for both academics and practitioners and provide recommendations for future IT offshoring uncertainty research.

IT OFFSHORING

Organizations today follow a variety of approaches when entering into an IT offshoring arrangement. These approaches include: the use of foreign subsidiaries, foreign acquisitions,

offshore development centers, joint ventures or alliances, and foreign contracting (Carmel & Agarwal, 2002). The ambiguity in the definition and many forms of IT offshoring complicate an already challenging decision for organizations. An expanded definition by Davis et al. (2006) indicates offshoring to be accomplished in one of two ways. First, the organization may outsource some of its activities to service providers in other countries who hire, train, supervise and manage its (i.e., the client's) personnel. Second, the client organization may set up service operations in other countries where the operations are managed by its own staff located in those countries rather than by the outside service provider. Barthelemy and Geyer (2005) also define outsourcing as either (1) a contract with an outsourcing vendor or (2) a client setting up their own IT subsidiary offshore (i.e., captive-outsourcing). For the purpose of this paper, we apply a general definition to offshoring where we focus on the IT offshoring decision to include the client firm utilizing a selected IT offshoring model.

Specifically, in this paper we focus on the following offshoring models: joint ventures, captive offshoring, third party offshoring, and an offshoring arrangement located onsite (i.e., onsite captive offshoring model). The offshoring models differ based on the amount of equity or investment that is made by the client firm and also on the degree of learning occurring as a result of the investment. In an offshore captive model the client firm invests, owns and operates a subsidiary in an offshore location. The client firm is in charge of hiring and operating the offshore facility utilizing the offshore resources. In an onsite captive offshoring model, the client firm brings offshore resources to work at the onsite location by collaborating with a third party. That is, the third party offshore vendor will provide the human capital resources by relocating the vendor employees to the client's location to perform the IT activities. The vendor resources will be managed by and report to the client's project leaders. In a joint-venture model, the client and vendor firm share the investments needed to operate offshore. Client firms may also choose to hire a third party offshore vendor to supply the IT activities to the client firm. The vendor is located offshore and performs the IT activities outside of the home country of the client firm. Hiring a third party vendor requires less equity or upfront investment when compared to the equity-based offshore models.

IT OFFSHORING AND ENDOGENOUS VS. EXOGENOUS UNCERTAINTY

In this paper uncertainty in the offshoring setting refers to the prospect of unanticipated developments in the technological, business, or political environments of the offshore vendor country which are of particular concern in the offshoring decision, given the global nature of IT offshoring (Mirani, 2006). Studies often cite a wide variety of uncertainty definitions. For example, Miliken (1987) defines uncertainty as a "perceived inability to predict accurately" due to a lack of "sufficient information." Uncertainty can also be defined as a condition in which one cannot ascertain the probability of an event and therefore cannot insure against its occurrence (Miller & Shamsie, 1999; North, 1990). In order to develop a parsimonious theoretical

framework to effectively capture the various uncertainties involved in the IT offshoring decision, we introduce and rely on the distinction between endogenous and exogenous uncertainty (Dixit & Pindyck, 1994; Folta, 1998). Uncertainty is endogenous when a client is able to reduce or dispel the uncertainty through its own actions. For example, uncertainty associated with operating in a very culturally different environment diminishes as a firm gains experience about cultural norms and business practices (i.e., customer preferences, partner relationships, supplier network etc.). That is, the reduction of endogenous uncertainty is dependent on the client firm's learning process (Folta, 1998; Roberts & Weitzman, 1981). In contrast, exogenous uncertainty arises externally to the firm and is mostly independent of the firm's actions; it includes factors such as unforeseen actions by external entities (i.e., regulatory bodies, governments etc.) (Folta, 1998). Firms have little or no control over the evolution of exogenous uncertainty. Client firms have to deal with a variety of exogenous uncertainties while operating in a host country (Hill, Hwang & Kim, 1990). These include political uncertainty (Kobrin, 1982; Miller, 1992), legal and regulatory uncertainty (Teece, 1986; Teisberg, 1993), and macroeconomic uncertainty (Hassett and Metcalf, 1999; Miller, 1992). For example, a client firm's actions have marginal or no effect on reducing exogenous uncertainty (i.e., political regime change). However, it can be reduced by a passive observation and a general learning of the host country's environment.

As seen from the above discussion, a client firm may face both endogenous and exogenous uncertainties when examining its own IT offshoring decision. Viewing IT offshoring models as a special kind of real options, we draw on the real options and organizational learning literature to develop a theoretical framework that allows for effective differentiation and understanding of uncertain environments and its effects on the IT offshoring decision.

THEORETICAL BACKGROUND

Traditionally, offshoring has been viewed as a unique form of foreign market entry; one that is focused on access to labor markets. There are several theoretical perspectives in this body of literature that provide valuable insights into the offshoring model choice. For example, the transaction cost theory (TCT) (Williamson, 1975) has been widely applied to analyze the IT outsourcing decision from an economic perspective (i.e., Lacity & Willcocks, 1996; Wang, 2002). It suggests that when asset specificity is low, and transactions are relatively frequent, the transactions will tend to be governed by markets and the offshoring decision will move towards utilizing an offshore third party. On the other hand, high asset specificity and uncertainty will lead to transactional difficulties and transactions will be held internally within the firm, or vertically integrated through a client sponsored offshore subsidiary (captive offshoring).

The proponents of the internalization theory (Buckley & Casson, 1976) posit that multinational enterprises (MNEs) internalize their operations when faced with uncertainty surrounding a transfer of their proprietary knowledge. In the context of offshoring, a client might choose to open and operate their own offshoring subsidiary instead of partnering with a

host country vendor when the risk of opportunism by the partner is high. This view draws on the organizational learning literature and suggests that cumulative international experiences enable MNEs to reduce uncertainty. Likewise, a stage model of offshoring elaborated by Carmel and Agarwal (2002) suggests that client firms manage uncertainty by choosing offshoring models based on their learned experiences. Specifically, their field work identified four IT offshoring stages adopted by US firms: Stage 1-Offshore Bystanders are firms that do not offshore at all, but may have a few advocates pushing the idea, Stage 2-Offshore Experimenters are pilot testing sourcing of non-core IT processes offshore., Stage 3 – Proactive Cost Focus are companies that take a proactive cost focus and seek broad, corporate-wide leverage of cost efficiencies through offshore work, and Stage 4 – Proactive Strategic Focus – are companies that take a proactive strategic focus and view offshore sourcing as a strategic imperative. While the IT offshoring research has grown into a large body of work, the existing literature has not sufficiently explained the relationship between the degree and type of uncertainty and offshoring model choice. Specifically, each of the previously mentioned theoretical approaches tends to focus on only one kind of uncertainty and its impact on the choice of the IT offshoring model.

The real options theory provides a framework that overcomes such limitation. The theory can be used to explain IT offshoring choices and help managers to account for the uncertainties that arise in such evolving environments (Trigeorgis, 1996). The strength in the real options theory is in recognizing the impact of uncertainties on investment decisions and the flexibility it provides to managers in making strategic decisions. Researchers have conceptualized real options as a theoretical framework in various environments such as equity joint ventures (Kogut, 1991), investments in emerging markets (Kogut & Kulatilaka, 1994), R&D projects (Mitchell & Hamilton, 1988) and IT infrastructure (Balasubramanian, Kulatilaka, & Storck, 2000; Fichman, 2004). One of the primary reasons for the growing interest in real options theory is the practical concern that strategic investment decisions are often made under uncertainty (Dixit & Pindyck, 1994). The primary advantage of holding a real option is that it offers flexibility to its holders by conferring them the option to defer (McDonald & Siegel, 1986), or an option to abandon (Myers & Majd, 1990). In order for real options to be viable, two conditions must be met. First, the decision must be characterized by uncertainty and second, the investment should not be easily irreversible. That is, once the decision is made, it cannot be reversed without incurring cost. IT offshoring can be viewed as a real option as it meets both criteria. The decision to offshore is surrounded by uncertainty (i.e., uncertainty dealing with foreign vendors, uncertainties arising from local environment) that is typically not associated with traditional domestic IT outsourcing or internal sourcing. In addition, the decision of a client to back-source (i.e. bring IT back in-house) or switch vendors (Lacity & Willcocks, 2000) can have serious financial implications. Thus, the offshoring decision is not easily reversible. Under conditions of uncertainty and irreversibility, holding an option represents the right to postpone the decision in order to resolve some of the uncertainty. In our case, this can be uncertainty surrounding the client's offshore vendors or the subsidiary's offshore host country environment. Once the IT offshoring model

decision has been made (i.e., the option has been exercised by making an investment in a subsidiary to be operated in another country), the resources spent to implement the strategy cannot be easily recovered if the IT offshoring decision is often revealed to be suboptimal.

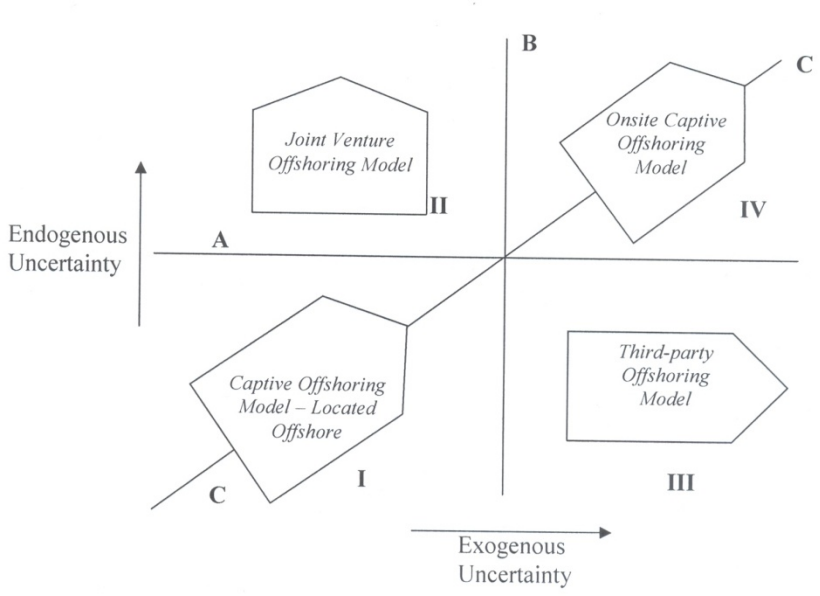
IT offshoring usually involves higher complexity and risks when compared to insourcing or domestic outsourcing because of the need to control the project remotely and to interact cross-culturally (Carmel & Agarwal, 2002). In addition, the client firm is also exposed to additional levels of uncertainty in regards to managing security across country and organizational boundaries. IT offshoring often entails IT assets and information to be in possession of an offshore vendor in another country and thus making the client's assets much more difficult to protect. Firms engaging in offshoring may also face uncertain political and economic instabilities of the offshore locations. One example is India (a leading provider of IT offshoring) and their unstable political relationship with Pakistan, where the two have been on the brink of war on a number of occasions. Economic uncertainties can also be substantial. An example is the Philippines' government's pressure to eliminate the generous tax incentives, which could eventually push up prices in the region (Carmel & Nicholson, 2005).

We should note that uncertainty is only one of many factors that influence a client's choice of offshoring model. Factors such as strategic alignment, cost, technology etc. all can have an impact on the clients' choice of offshoring model (i.e., Carmel & Agarwal, 2002; Kakabadse & Kakabadse, 2000; King & Malhotra, 2000). These factors, however, are beyond the scope of this paper whose primary focus is to gain a better understanding of the effects of uncertainty on IT offshoring model choice.

IT OFFSHORING-UNCERTAINTY FRAMEWORK

The impact of uncertainty on the IT offshoring decision has been suggested to be critical to organizational performance (Hahn et al., 2009). Companies whose offshoring initiatives fail to meet their expectations typically make one of the following mistakes (Aron & Singh, 2005). First, companies do not spend enough time evaluating which aspects (i.e., processes, application development, and customer service) they should offshore and those that they shouldn't. Second, firms do not take into account all of the risks that are inherent within the offshoring context. Client firms often fail to realize that once they transfer their processes, their vendors could gain the upper hand as the power in the relationship shifts from the clients to the vendors. There is no guarantee that offshored projects will be any more successful given the time delay, cultural, financial, technical and legal issues. The complications of IT offshoring can make it very easy for firms to underestimate the difficulty of the offshoring engagement and eventually terminate the offshoring relationship. Offshoring usually involves higher complexity and risks because of the need to control the project remotely and to interact cross-culturally (Carmel & Agarwal, 2002). As a result, a framework is necessary to support client firms in managing the uncertainties inherent to IT offshoring.

FIGURE 1
Two Dimensions of Offshoring Uncertainty: Endogenous and Exogenous



The suggested framework (Figure 1) considers uncertainty to consist of two dimensions – endogenous and exogenous – which are independent and capture wholly different types of uncertainty. Although the occurrence of uncertainty is a continuous phenomenon, we use a dichotomous categorization for the sake of simplicity. A firm can be perceived to be experiencing either high or low levels of endogenous uncertainty or high or low levels of exogenous uncertainty. An illustrative exercise to introduce the relationship between the uncertainties is to consider moving along various paths from any given point in a hypothetical two-dimensional space as depicted in Figure 1. Consider first moving eastward along line A, increasing exogenous uncertainty while holding endogenous uncertainty constant at a relatively low level. Firms experience constant endogenous uncertainty along this path and correspondingly increased levels of exogenous uncertainty. Likewise, when moving northward along line B from the midpoint of the exogenous uncertainty axis and, increasing endogenous uncertainty while holding exogenous uncertainty constant a firm could also simultaneously experience an increase in both endogenous and exogenous uncertainties (i.e., moving in the northeast direction along line C). Advancing along both the dimensions of uncertainty increases the challenges a client faces when compared to the previous two scenarios. In the following sections, we discuss the unique problems encountered by client firms within each quadrant in making strategic decisions regarding IT offshoring. We identify examples of offshoring models for each scenario that could provide effective means to manage these uncertainties. These

examples are not a comprehensive list of possible IT offshoring models, but to an extent represent a selection of those that are prominently discussed in the existing literature.

QUADRANT I: LOW ENDOGENOUS UNCERTAINTY AND LOW EXOGENOUS UNCERTAINTY

From the client firm's perspective, Quadrant I (Figure 1) represents the most desirable uncertainty case. In this situation, the client firm has a good understanding of the host country culture, technology and the outsourced activity. Moreover, it also has a good understanding of the host country macroeconomic environment (i.e., legal, political, etc.). An example of this scenario would be a US located client firm offshoring its quality management task (i.e., application testing) to an IT firm located in Canada. In such a case, because of relatively low levels of endogenous and exogenous uncertainties, client firms have all the information needed to make a decision regarding their offshoring model. To the extent that the client firm is already familiar with the partner firm, host country culture and institutional framework, there is no need for the client firm to delay its decision to invest. Viewing the offshoring decision from the real options perspective, under conditions of both low endogenous and low exogenous uncertainty, client firms do not have to take an option to defer the action to offshore (McDonald & Siegel, 1986). That is, the client firms do not have to delay or postpone the offshoring decision to another time period as both endogenous and exogenous uncertainties are low. In addition, given the low need to proactively manage uncertainty, they are likely to choose a "captive offshoring model" that is an offshoring subsidiary owned and operated by the client firm that is located in a foreign location. When both endogenous and exogenous uncertainties are low, the client firm tends to have accurate information about the host country's culture and institutional framework. This enables the client firm to pursue captive offshoring which tends to have the lowest coordination and production costs (Cha, Pingry & Thatcher, 2008). Achieving effective collaboration is difficult in global offshoring projects as there are often multiple boundaries that must be bridged simultaneously (Espinosa, Cummings, Wilson & Pearce, 2003; Hinds & Bailey, 2003).

Captive offshoring models avoid the need for a partner and costs including search costs associated with looking for and screening of potential local vendors and costs associated with contract monitoring and enforcement. Offshore captive operations also tend to have low operating costs. Rao (2004) also suggests that captive offshoring models provide firms with the benefits of tax incentives offered by the local offshore governments and access to skilled labor force all contribute to the growth in the captive offshore model. Thus, when there is little need to manage either exogenous or endogenous uncertainty, a captive offshoring model is the most desirable option.

In sum, the scenario represented in Quadrant I represents the most favorable situation for the client firm. Ceteris paribus, client firms are likely to pursue captive offshoring model based in a foreign location when endogenous and exogenous uncertainty is low. Thus we suggest:

P1. A captive offshoring model will be favored over other offshoring models (i.e., joint venture offshoring) by client firms when operating in host countries with low endogenous and low exogenous uncertainty environments.

QUADRANT II: HIGH ENDOGENOUS UNCERTAINTY AND LOW EXOGENOUS UNCERTAINTY

Quadrant II (Figure 1) depicts a more challenging situation for client firms than Quadrant I. In this scenario client firms face many endogenous uncertainties that could influence their IT offshoring model selection. Endogenous uncertainties as defined earlier include uncertainties that the firm has the ability to take action to reduce or dispel through their learning and development of capabilities. The proprietary knowledge and capabilities developed as a result of coping with endogenous uncertainties can then be used by the firm to manage the endogenous uncertainty in other host countries (Luo, 2002).

One endogenous uncertainty faced by offshore client firms includes the offshore location's cultural uncertainty. Cultural uncertainty is related to the difficulty of operating in a host country due to lack of understanding of the foreign location's values, beliefs, and customs. Cultural incompatibility has been cited as a major stumbling block and concern in international sourcing (Carmel & Nicholson, 2005), but the effects can be mitigated by the intercultural competence of the client and vendor firms (Haried & Ramamurthy, 2009). Research indicates that the lack of cultural readiness could have serious negative effects (Barkema, Bell & Pennings, 1996; Delmonte & McCarthy, 2003). The rate at which the client can learn about the host country culture depends on the "distance" of this culture to the client. The more distant the culture of host country, the harder it is for the local firm to quickly learn that culture as it lacks the absorptive capacity to assimilate this new knowledge (Cohen & Levinthal, 1990). Under such conditions, it is prudent for the local firm to undertake sequential learning so that it could develop the requisite absorptive capacity to develop knowledge about the host country culture (Folta, 1998). Indeed, in order to understand "distant" cultures, firms generally form collaborative ventures with host country partners to help navigate and understand the ways of doing business in these countries (Kogut & Singh, 1988).

Using local partners to overcome cultural uncertainty presents a firm with another type of endogenous uncertainty -- the partner uncertainty. This is typically because of the possibility of opportunistic and self-seeking behavior on the part of the host country partners (Hennart & Zeng, 2002; Williamson, 1975). The uncertainty surrounding partner opportunism is further heightened due to information asymmetry and difficulty in evaluating potential partners

(Balakrishna & Koza, 1993; Woodcok, Beamish & Makino, 1994). However, over time, firms become better at assessing their local partners and as they develop alliance management capability (Ireland, Hitt & Vaidyanath, 2002), the information asymmetry gradually decreases.

The real options literature posits that in order to resolve endogenous uncertainty firms must undertake projects in stages so that learning can occur incrementally (Chang 1995; Folta, 1998). Research on real options and related work on organizational learning suggests that joint ventures are especially suited for learning about new markets and building capabilities (Kogut & Kulatilaka, 1994; Luo, 2002). In the context of foreign market, joint ventures represent a real option (Kogut, 1991). They help client firms to proactively manage uncertainties by giving them the strategic flexibility to increase commitment if their understanding of the host country market improves and, correspondingly, increasing their ability to exit the market quickly without incurring substantial loss should the host country market situation worsen.

From the point of view of the IT offshoring literature, the client firm's investment in a joint venture (JV) represents an important mechanism by which a client can leverage and acquire new competencies and learn to handle the inherent endogenous uncertainties. Thus, based on the above discussion we argue that clients will undertake a joint venture when utilizing host countries with high endogenous uncertainty and low exogenous uncertainty because the initial costs (due to loss of control) will be more than offset by the gains in learning and strategic flexibility. By opting for equity joint venture offshoring model, clients can manage and limit the effects of the endogenous uncertainties by relying on the partners' resources, including their knowledge of the host country culture, market, and suppliers (Inkpen & Beamish, 1997). Thus, *ceteris paribus*, we state:

> *P2: A joint venture offshoring model will be favored over other offshoring models (i.e., third party offshoring model) by client firms when operating in host countries with high endogenous and low exogenous uncertainty environments.*

QUADRANT III: LOW ENDOGENOUS UNCERTAINTY AND HIGH EXOGENOUS UNCERTAINTY

In Quadrant III (Figure 1), the client firms experience high exogenous uncertainty and relatively low endogenous uncertainty. This situation is more ambiguous than the previous situation because in contrast to endogenous uncertainty, client firms have little or no control over the evolution of exogenous uncertainty. Client firms have to deal with a variety of exogenous uncertainties as introduced earlier: political, legal, regulatory, and macroeconomic uncertainty. Client firms engaging in IT offshoring face uncertainties through the threat of major disruptions arising from political upheaval or war in an offshore host country. Typically, businesses prefer to operate in offshore location countries that are politically stable. However, wage rates tend to be lower in less stable countries, thus organizations are often tempted to operate in relatively

unstable environments (Davis et al., 2006). Firms also face increased intellectual property issues when offshoring sensitive software development and maintenance to unstable offshore locations. When their resources are not well protected due to weak intellectual property rights regime, firms are more likely to undertake a wait-and-see approach rather than committing large equity upfront (despite the desire to increase control over the venture).

Another important exogenous uncertainty that could impact the client is the macroeconomic uncertainty of the host country. Miller (1992) defines macroeconomic uncertainty as the unpredictability of fluctuations in economic activities and prices in a host country. For example, the global economic crisis and the 2008 terrorist attack in Mumbai, India produced significant uncertainties for the client firms who have offshored IT activities to India and for those considering offshoring to India (Srivastava, Lakshman & Hamm, 2008). These uncertainties are prompting the client firms to consider limiting or discontinuing their offshore investments in India.

A number of studies have supported the view that firms can reduce their exposure to exogenous uncertainties by limiting their levels of direct ownership (Brouthers, 2002; Kobrin, 1983). In the IT outsourcing literature, when contractual hazards are perceived to be high, meaning that the formal contract cannot cover or address the uncertainties involved in the relationship, client firms tend to prefer a client-vendor relationship (Barthelemy, 2003). When the exogenous uncertainties are high, it is prudent for firms to limit their vulnerability by lowering their resource commitment and making sure that they can exit the market quickly without incurring substantial loss should the conditions worsen. Under conditions of high ownership levels, such as in an offshore captive offshore subsidiary, the large investments are not as desirable as they would lead to a commitment level that is difficult to reverse. Previous research indicates firms entering countries with high macroeconomic volatility are less likely to undertake large commitments (Goldberg & Kolstadt, 1995) as flexibility becomes paramount in mitigating this type of uncertainty (Sutcliffe & Zaheer, 1998). Similarly, when political uncertainty is high, firms tend to make lower commitments (Delios & Henisz, 2000). Rather than be constrained by a high ownership offshoring model a firm should engage in an IT offshoring model that allows it to respond to the exogenous uncertainties. The more adaptive mode of entry is the third party offshoring model when compared to other offshoring models. Although the third party offshoring model is associated with less control, the model offers increased flexibility to adapt to changing environments. Furthermore, while a joint venture offshoring model is important when learning and developing new capabilities for dispelling endogenous uncertainty under conditions of exogenous uncertainty; firms have minimal control over the reduction of exogenous uncertainty. In other words, exogenous uncertainty evolves independent of the client firm's actions. Moreover, as the endogenous uncertainty is relatively low in this situation, firms do not have to take any actions to reduce endogenous uncertainty. This suggests that, *ceteris paribus*:

P3: A third party offshoring model will be favored over other offshoring models (i.e., captive offshoring model) by client firms when operating in host countries with low endogenous and high exogenous uncertainty environments.

QUADRANT IV: HIGH ENDOGENOUS UNCERTAINTY AND HIGH EXOGENOUS UNCERTAINTY

At times client firms experience the situation depicted in Quadrant IV (Figure 1). Here endogenous and exogenous uncertainties jointly describe the state that offshore client firms experience during the offshore model selection. We have already discussed that while building capabilities that minimize endogenous uncertainties is possible, it is extremely difficult, if not a significant challenge to accomplish the same as in case of exogenous uncertainty. We argue that learning in environments with high levels of exogenous uncertainty is less manageable and transferable as the decision makers are ignorant of the underlying causes of the uncertainty and the *ex post* environment is unclear. The ability to build new capabilities is hindered when the firms cannot predict the outcome or assign a probability to it. Indeed, Luo (2002) observed that capability building is negatively related to environmental complexity (which contained macroeconomic, political/legal and socio-cultural dimensions).

Our contention is that client firms that experience high exogenous uncertainty and high endogenous simultaneously will first choose the onsite offshoring model. By bringing resources onsite client firms can reduce some of endogenous uncertainty (i.e., cultural uncertainty) and lower the level of endogenous uncertainty experienced. That is, the firm can learn about partner, host country culture, etc., by interacting with the third party resources onsite. This arrangement also allows the client firms to mitigate the influence of exogenous uncertainty as the job tasks are being performed in the client's location. In other words, this allows the client firms to learn and resolve endogenous uncertainty without being distracted by exogenous uncertainty. After they have developed the necessary capabilities to lower endogenous uncertainty (i.e., reduce the endogenous uncertainty through experience), client firms will pursue one of three offshoring models that we discussed earlier (i.e., captive offshoring, third party offshoring or joint venture offshoring) depending on the exogenous uncertainty in the host county at that time. *Ceteris paribus*, when dealing with both high endogenous and exogenous uncertainties simultaneously, offshore client firms will first choose onsite offshoring arrangement with a third party vendor.

P4: When dealing with both high endogenous and high exogenous uncertainty environments client firms will first prefer to enter offshoring relationship with an onsite captive offshoring model. After developing capabilities to deal with the endogenous uncertainty, client firms will choose another offshoring model (i.e., captive offshoring) depending on the exogenous uncertainty in the host country at that time.

ILLUSTRATIVE CASE EXAMPLE

To further illustrate the relationship between IT offshoring strategy and endogenous and exogenous levels of uncertainty we present a case that demonstrates a shift in offshoring strategy as classified in our offshoring uncertainty framework. The case example is taken from a series of interviews conducted during December 2006 through June 2007 with a client firm who shifted their offshore strategy from Quadrant IV to Quadrant I due to the realization of endogenous and exogenous uncertainties. For each case, we included interviewees from business and technology functions along with both managerial (i.e., senior business and technology managers) and operational (i.e., business analysts, system engineers) level stakeholders. For the purpose of this paper, the selected case example demonstrates an offshore model strategy shift from Quadrant IV to Quadrant I (i.e., the most dissimilar types in terms of their uncertainty combinations of low to high) allows us to highlight the role of uncertainty and IT offshoring strategy. Upon the request of the client firm involved, the client name has been changed to maintain anonymity.

HEALTHCENTER – OFFSHORE MODEL STRATEGY SHIFT FROM QUADRANT IV TO QUADRANT I

HealthCenter is a diversified industrial corporation, operating in a number of segments: from infrastructure, finance, healthcare, and industrial manufacturing. In 2004, HealthCenter started to investigate different offshore strategies to provide technical and network support utilizing resources in India. The offshore initiative provides initial network and technical support, 24 hours a day, 7 days a week. Examples of the support provided include: network security, infrastructure issues, connectivity, database, applications and general security issues. The goal was to offload the troubleshooting and support issues to India and reduce the turnaround time for issue resolution. The utilization of India resources for support would allow the US based employees to concentrate on design and major projects originating from the U.S.A based HealthCenter. Over the lifetime of the offshore initiative, HealthCenter underwent a shift in their offshore strategy. They initially selected the onsite captive offshoring strategy (Quadrant IV) and evolved into the captive offshore strategy located offsite (Quadrant I) to better fit the uncertainties present in their offshore relationship. Early on in the project, the plan was to bring offshore personnel provided by an offshore vendor firm to the US location to work side by side with the US HealthCenter personnel. The goal was to learn about the Indian culture, test the waters and leverage the intellectual capital of India. However, as HealthCenter matured in their offshore operations and learned to deal with the endogenous and exogenous uncertainties involved, they were able to shift their offshoring strategy to better fit the uncertainties present in the relationship.

Early on from an uncertainty perspective, HealthCenter viewed both the exogenous and endogenous uncertainties to be extremely high. Since this was one of the first offshore experiences of HealthCenter, endogenous uncertainty at this point was seen as high and uncontrollable. They had little understanding and experience in working in the Indian cultural context. From an exogenous standpoint in Quadrant IV, a major uncertainty from the client's perspective was the macro-economic situation of India. Offshore workers were jumping jobs frequently, resulting in loss of productivity and performance due to all of the retraining that was necessary. The senior business manager pointed out that "there was a lot of job hopping… turnover was very high in the IT area…. what people would do is they would ramp their skills up, boom jump a job and get another 30% increase, then boom, go to another job, get another 30%, you can't blame them for trying to increase their standard of living. But we would have to keep retraining, and that became an issue for us." Overtime, HealthCenter determined that opening and operating their own captive offshore center (Quadrant I) would be a strategy to help minimize the exogenous macroeconomic uncertainty.

In addition, cultural issues appeared to play a key role in the initial concerns HealthCenter had in regards to their selected offshore model strategy. However, as HealthCenter garnered experiences in working with the offshore resources, alternatives were uncovered that could limit the effects of cultural issues. The systems engineer noted "one thing that I learned early on was that they don't like to confront us at all. Even though they disagree with us, they nod, say yes, so later on we found out that we basically have to tell them that it is ok to tell us that you don't agree… in their culture you don't go against your boss or manager, you don't argue back with them, whatever they say is right, were not always right and we know that, but sometimes it is good to disagree with the boss." Onsite HealthCenter personnel indicated concerns over the passive nature of the offshore resources. The senior business manager noted that a challenge was "taking a passive culture and making the people a little bit more aggressive to fit the HealthCenter style." The senior business manager noted "people are more passive, because everything is very polite and that is just to me the Indian culture... they need to be aggressive, when they grab that problem, take it and solve it." HealthCenter was able to control some of the endogenous uncertainties by confronting the offshore personnel and explaining to the expectations of open communication in the relationship that appeared to be drastically different due to the offshore culture.

Communication challenges also arose due to cultural issues. HealthCenter had to play an active role in managing and reducing this endogenous uncertainty. The senior IT manager noted "understanding them was a challenge…so chat was used… it was better if they were typing rather than speaking." Non-verbal communication challenges also emerged due to the cultural differences. During our discussions, the client's business staff noted that "I had them saying yes to me, but they were shaking their heads to me in the American way as no, and then another group of them were saying no to me and shaking their heads to me in an American way of yes." As the offshore experiences of HealthCenter matured they were better able to address and

manage these differences by directly addressing the communication challenges that were not understood early on during their offshore relationship.

Economics was another driving force behind the offshore model shift. Early on, bringing Indian personnel onsite to the US location was a cheaper economic strategy than staffing the IT troubleshooting department with US based employees, due to the labor arbitrage that existed among the two countries. The senior business manager pointed out that "the deal was where we would have people come here initially, and then as they did the knowledge transfer they would go back to India and do the work. But what really ended up happening was because there were different rates. If you work onshore at HealthCenter the vendor was charging a certain rate, if the personnel were located and worked offshore the rate went way down. It actually worked for a good couple years, and then the contract kind of went sour, due to the fact that we had way too many people being onshore instead of offshore." At this point in time HealthCenter reevaluated their offshore strategy to better fit the uncertainties that were learned over their initial offshore experiences.

After a few years of experience and an increased understanding of the uncertainties involved, they reevaluated their perceptions of the endogenous and exogenous uncertainties involved to better fit their offshoring strategy to their specific environment. They determined that the early concerns over the cultural issues were not as extreme as initially believed. They also determined that they could influence some of the wage rate issues and job hopping/turnover issues that were rampant in India. As a result, HealthCenter shifted their offshore model into Quadrant I, thus running their own offshore captive center. HealthCenter invested and constructed a dedicated building just for technology and network support that employed around 300 people who were considered full HealthCenter employees. Factors driving the shift according to the senior business manager "we were actually able to reduce our costs a lot… the big difference was that early on we were spending a million dollars on contracting costs, and we were in the 80-20 model. So we would be 20% HealthCenter and 80% contracted… as we learned more about the opportunities in India we thought we were spending way too much on contractor costs. So what we would do is leverage the intellectual talent on India, by opening our own location in India and make the resources that were contractors HealthCenter employees, which really helped lower our turnover and job hopping." Overall, HealthCenter according to its business manager indicated that "I just think it has proved out to be a cost effective way to lower cost of ownership as well as running operations." As a result, it appears that HealthCenter was able to select an offshore model that best fit the uncertainties that were present in their offshoring relationship.

The case of HealthCenter provides a valuable early investigation and demonstration of the role uncertainty plays in a firm's offshore strategy selection. The case also illustrates how a firm's IT offshoring strategy may shift after exogenous and endogenous uncertainties are learned. Further case investigations and empirical work are highly recommended to illustrate the

use of our framework to guide firms in matching their selected offshoring model to the endogenous and exogenous uncertainties faced by a client firm.

DISCUSSION

In this paper, we sought to develop a theoretical framework that would help explain IT offshoring model choices. In doing so, we sought to contribute to the literature on international IT sourcing, commonly referred to as IT offshoring, by highlighting how uncertainty affects a client's IT offshoring decision. In addition, in our theoretical approach (drawing on the real options theory) we overcame some of the limitations with current theoretical approaches that relied on a one-dimensional view of uncertainty. We suggest that the nature of uncertainty is a combination of two different dimensions: endogenous and exogenous. Using the two-dimensional framework to describe the client host country environments allows us to meaningfully and parsimoniously understand the challenges faced by clients while operating in uncertain host country environments. Our illustrative example demonstrates the importance of incorporating uncertainty into the offshore strategy decision and the importance of fit in regards to offshore strategy and the uncertainties present in offshoring. This framework allows for a more precise, theoretically grounded description of uncertainties facing IT offshoring clients in their IT offshoring strategy selections. In particular we suggest that endogenous uncertainty can be influenced by the actions of clients (i.e., by forming joint venture offshoring relationship a client can develop capabilities to mitigate the effects of endogenous uncertainty on the firms operations and performance). In addition, we argue that client actions have little influence on exogenous uncertainty as the environments are too ambiguous for capability development to take place.

Prior research findings on uncertainty and offshoring client firm behavior support our theory. Client firms desiring greater control (i.e., decreasing uncertainty) prefer a subsidiary IT offshore entry mode (Jagersma & van Gorp, 2007). Fitzgerald and Willcocks (1994) suggest that more strategic partnerships are ideal when business and technical uncertainty are high and loose contracts are written. Lee, Miranda, and Kim (2004) observed that firms desiring cost efficiency in their outsourcing relationships would be best served by arm's length relationships whereas those wishing to derive strategic competence or technology catalysis needed to develop network type relationships with their providers. In practice all contracts contain both complete and incomplete sections wherein the governance mechanisms can be viewed as a range of alternatives from a very tight and lengthy contract to no contract with a true partnership relationship. The limitations of contract can be avoided with the use of the subsidiary offshoring model since the client firm is operating the offshore venture. In other offshoring models, a complete contract specifies all of the actions that each party is responsible for in the relationship. Such a contract might reduce the uncertainty faced by organizational decision makers and the risk of opportunism created in the offshoring agreement. However, situations will develop

during the course of a multi-year outsourcing contract (i.e., technological obsolescence, political turbulence) that the contract might not cover. . Thus, it is important to incorporate flexibility into an outsourcing contract (Fitzgerald & Willcocks, 1994; Willcocks and Kern, 1998). Flexibility includes the option for the client to change service requirements and for the vendor to change the means by which service requirements are met (Clark, Zmud & McCray, 1995). Often it is the "unwritten contract" between the vendor and client that strengthens the relationship to the point that it becomes an invaluable partnership and relationship (Webb & Laborde, 2005).

Previous outsourcing research has also explored the relationship between success and uncertainty. Research has hypothesized a negative relationship between the level of environmental uncertainty and the outcome of outsourcing (i.e., less successful outsourcing in volatile environments). However, the findings are inconclusive (Dibbern, Goles, Hirschheim & Jayatilaka, 2004). Wang (2002), following transaction cost theory, finds a negative relationship between uncertainty and outsourcing success, whereas Poppo and Zenger (1998) contradict this. One reason for this could be the erroneous assumption in much of the existing offshoring literature that different types of uncertainties (i.e., political, cultural etc.) have similar effect on offshoring decision. Thus, our framework provides valuable insight and extensions to the offshoring literature examining the role of uncertainty and IT offshoring success.

Additionally, the management literature also supports our framework. Earlier studies have found that the greater the host country uncertainty the greater the likelihood that firms will opt for licensing rather than wholly-owned subsidiaries (Kim & Hwang, 1992), and joint ventures rather than wholly-owned subsidiaries (Bell, 1996). This suggests that clients are reluctant to commit resources and prefer to maintain some degree of strategic flexibility when uncertainty is high. Thus, as we posit throughout this study, uncertainty (both endogenous and exogenous) plays a critical role in the IT offshoring decision and should not be ignored.

RESEARCH IMPLICATIONS

We anticipate that the insights offered by this study will prove useful to scholars interested in studying success and international IT sourcing strategies. On a practical front, this study shows that attention needs to be given to the role and types of uncertainty inherent to the IT offshoring decision. Often the level and type of uncertainty appears to have been ignored or, alternatively, studies focused on only one of many types of uncertainties. Scholars need to recognize that uncertainty needs to be accounted for and action may need to be taken to support a successful offshoring initiative.

By integrating the organizational learning and real options theory, our paper provides a significant contribution to the IT offshoring arena. The extant management literature suggests that under uncertainty firms must take collaborative ventures rather than investing in a wholly owned subsidiary. The literature also stresses the importance of developing "complete" contracts, which is unrealistic in most offshoring circumstances. However, the same literature is

less clear regarding the "type" of offshoring model a firm must undertake in a particular type of uncertainty (endogenous vs. exogenous). Moreover, it understates the relationship between learning and uncertainty. Our paper highlights the notion that firms can dispel endogenous uncertainty through learning whereas they have no control over exogenous uncertainty. It also provides not only a fuller, more holistic explanation of the offshoring model choice but offers normative recommendations to IT offshoring client managers.

PRACTICE IMPLICATIONS

Our theory is particularly relevant to practitioners given the exponential growth of IT offshoring investments made by client firms in emerging global markets. As Luo (2001) observed, while uncertainty is present in most markets, it is typically widespread in emerging and under developed economies. Thus, our two-dimensional framework of uncertainty has several implications for client managers making strategic IT offshoring decisions. First, the framework highlights the importance of distinguishing the uncertainty in a particular country from those that are present in other countries. Second, it emphasizes learning as a way of reducing or dispelling endogenous uncertainty and underscores the difficulty that client firms face in developing capabilities to counter exogenous uncertainty.

Clarifying the role and type of uncertainty inherent to the IT offshoring decision should help client firms determine a fit between their IT offshoring strategy and the associated uncertainties to help ensure success. Client firms may start by clarifying the type of uncertainty that they are experiencing or may experience due to context of the offshoring relationship. Client firms who are able to predict and address any uncertainties and fit their IT offshoring strategy to the uncertainties that may be encountered will be in an improved position of success probability when compared to firms who lack a preparation and understanding of the uncertainties inherent to IT offshoring.

FUTURE RESEARCH

Several additional directions for future research present themselves as a result of this analysis. Future research can empirically examine the impact of different uncertainties on the IT offshoring model decision in various regions. IT offshoring practices tend to be more mature in the USA when compared to other locations and could lead to potential differences in the desired client outcomes (Koh, Ang & Straub, 2004). Future research may want to focus on the various offshore vendor locations (i.e., India, China, and Brazil). In addition, research may want to include various client locations that are purchasing the IT offshoring (i.e., USA, Canada, and UK). By incorporating diverse client and vendor locations, we may gain unique insight in regard to how uncertainty is managed.

Our illustrative case example provides some indication that client firms perceptions of endogenous uncertainty are resolved through learning. An interesting venue for future research is the issue of client's evaluation of uncertainty (endogenous and exogenous) and how it manages the uncertainty. Such research might explicitly examine the differences across various client stakeholder groups and trace their evolution. As the relationship and experiences mature, client firms/stakeholders may refine/redefine their assessment of uncertainty. This suggests that longitudinal studies may be needed to consider the uncertainty dimensions at different stages of the relationship. Future research may also seek to explain why these evaluations change. For example, is the change due to learning or is it due to institutional effects (i.e., imitative behavior). In sum, our framework provides rich avenues for future researchers to pursue.

CONCLUSION

The international sourcing of IT products/services is clearly a phenomenon that will not disappear in the foreseeable future having evolved from being a cost saving initiative to more of a survival strategy for an increasing number of organizations in today's economic climate. The study's expanded view of the uncertainties involved in the IT offshoring decision offers some unique insights into how client firms need to evaluate the various levels of uncertainty and fit their IT offshoring strategy to both endogenous and exogenous uncertainties. Our illustrative case study lends some support to our conceptual uncertainty framework. We hope our this work will fuel further research on the influence of uncertainty in international sourcing decisions to help ensure organizations realize the most effective fit for their IT sourcing needs.

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THE MEDIATING ROLE OF WORK-LEISURE CONFLICT ON JOB STRESS AND RETENTION OF IT PROFESSIONALS

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ABSTRACT

To enhance employee retention, organizations have introduced various initiatives, which have led mixed results. Based on a survey conducted in a large global bank, this study examines how various job stressors impact the retention of information technology (IT) professionals and how these impacts are mediated by work-leisure conflict. The results indicate that among all the job stressors, role ambiguity has the most adverse influence on retention. Work-leisure conflict partially mediates the negative relationship between role conflict and retention, and fully mediates the negative relationship between role overload and retention. The empirical findings imply that organizations should tackle role ambiguity with highest priority and relieve work-leisure conflict to effectively retain employees under job stress.

KEYWORDS: Job stress, retention, work-leisure conflict

INTRODUCTION

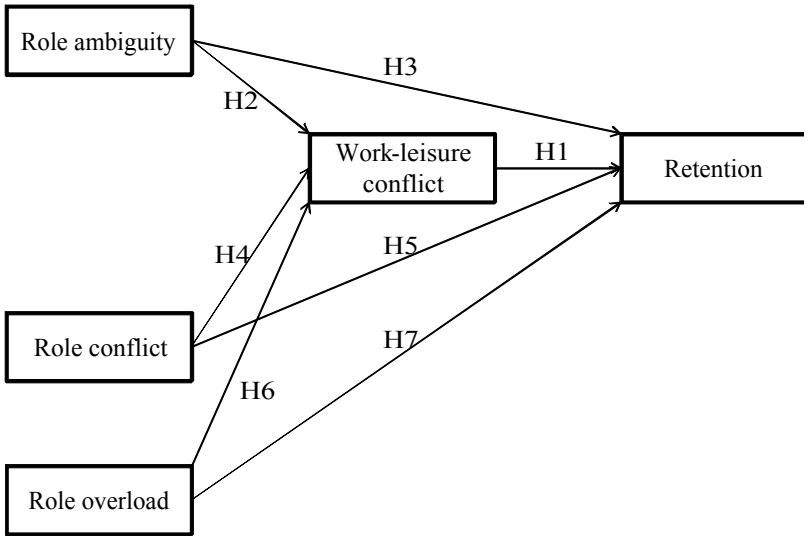
During the past two decades, information technology (IT) function has experienced a rapid growth in most organizations due to the intense competition in the field, which has led more demanding and complex roles for knowledge workers (Huarng, 2001; Fox, 2002; Maudgalya et al, 2006). Various studies (Li & Shani, 1991; Ford, Heinen & Langkamer, 2007; Slattery, Selvarajan & Anderson, 2009) have analyzed the consequences of these changes, and in this paper we attempt to take a deeper look at job stressors and determine how they impact the retention likelihood of IT employees. Other scholars (Judge & Colquitt, 2004; Monsen & Boss, 2009) have pointed out that work-life conflict is a significant factor in employee's decision to leave or retain in an organization. In particular, the importance of work-leisure conflict in terms of the impact of various job stressors on retention is another crucial area that this research addresses.

Through a survey of IT professionals in two large centers of a global bank, we collected 575 responses to test our model. Findings followed by discussions and practical implications are also presented.

THEORETICAL FRAMEWORK AND HYPOTHESES

To study the impact of work-leisure conflict on the relationship between job stress and retention, we propose the following theoretical framework (see Figure 1) with five interrelated components.

Figure 1 Conceptual Model of the Impact of Work-leisure Conflict on the Relationship between Job Stress and Retention



Work-life conflict reflects "how work spills over into family time" (Russell, O'Connell & McGinnity, 2009). Work spillover into personal life of employees can manifest itself in several ways such as: amount of time spent at work and away from home (Piotrkowski, 1979); mental preoccupation and absorption at work that impacts life outside work (Kanter, 1977); and, physical challenge of work can fatigue an employee and drain the energy needed for carry out and non-work activities – he or she becomes too tired to effectively engage in personal activities and relationships (Crouter et. al., 1983).

As an important part of nonwork variables, leisure is defined as "a period of time free from paid work or other obligatory activities" (Parker, 1971). Following this definition, leisure is perceived as "opposite" and "neutral" (unrelated) to work practices (Parker, 1971; Parker, 1983). Leisure can potentially compensate for negative experience or insufficient positive outcomes associated with paid work (Pearson, 2008). On the contrary, work-leisure conflict is negatively related to job satisfaction (Ford, Heinen & Langkamer, 2007), organizational commitment

(Siegel et al., 2005), retention (Monsen & Boss, 2009) and life quality (Rice, Frone & McFarlin, 1992). Based on these negative spillover effects, we hypothesize that:

H1: Work-leisure conflict is negatively related to retention.

Job stress in general has negative consequences on job outcomes for the employees and organizations, and it typically leads to higher intention to quit and increased employee turnover (Netemeyer, Burton, & Johnston, 1995). Following the literature (Netemeyer, Burton & Johnston, 1995; Gilboa et al., 2008; Monsen & Boss, 2009), we break down job stress into three main components: role ambiguity, role conflict and role overload. and specifically test their relationship to retention as well as how work-leisure conflict may play a mediating role this relationship.

Role ambiguity is the degree to which clear information is lacking. Specifically, IT professionals may deal with unclear expectations from users and changes under uncertain authority (Li & Shani, 1991). According to Ashforth and Saks (1996), role ambiguity is positively correlated with intention to quit. Similarly, Rafferty and Griffin (2006) argued that uncertainty at work in general was associated with intention to quit. When roles are not well defined, typical reaction of employees is negative leading to withdrawal which can eventually lead to employee leaving the organization (Harris & Mossholder, 1996). Based on these earlier findings of the multi-facet negative implications of role ambiguity we proposed the following two hypotheses:

H2: Role ambiguity is positively related to work-leisure conflict.

H3: Role ambiguity is negatively related to retention.

Role conflict is the multiple requirements and expectations from the role that impact role performance (Rizzo, House & Lirtzman, 1970) and clash due to their nature (Handy, 1985; Schi, 1996). It often occurs when conflicting demands are placed upon the individuals by their supervisors, peers, or subordinates, so this type of stress is more dominant in jobs that have vague descriptions and require abstract thinking and decision-making (Menon & Akhilish 1994). Since we are interested in job stress of IT professionals who are involved in such dynamics, we hypothesize:

H4: Role conflict is positively related to work-leisure conflict.

H5: Role conflict is negatively related to retention.

Role overload can manifest itself both qualitatively (difficult work) or quantitatively (too much work) and has been shown to have a relationship to various strain symptoms (physiological, psychological, and behavioral) among employees (Beehr & Newman, 1978; Cooper & Marshall, 1976; Almer & Kaplan, 2002). Ivancevich, Napier and Wetherbe (1983) found that work overload and time pressure were significant factors resulting IT work stress. Based on these negative consequences of role overload, we hypothesize:

H6: Role overload is positively related to work-leisure conflict.

H7: Role overload is negatively related to retention.

The combination of H1 and H2 shows the mediating role of work-leisure conflict in creating a positive effect towards role ambiguity on retention. H3 posits the direct effect of role ambiguity on retention. According to the clarification of conditions and decision points for mediational type inferences provided by Mathieu and Taylor (2006), we present H1, H2 and H3 to clearly emphasize mediating relationship without the confusion of indirect effects. Similarly, the combination of H1 and H4 shows the mediating role of work-leisure conflict on the positive effect of role conflict on retention. H5 posits the direct effect of role conflict on retention. The combination of H1 and H6 shows the mediating role of work-leisure conflict on the positive effect of role overload on retention. H7 posits the direct effect of role overload on retention.

METHOD

RESEARCH SETTING, DATA SOURCES, AND SAMPLING

We surveyed knowledge workers of Chinese and Indian origin, in a global European bank through an online survey. There were 577 complete responses obtained from two sites, for a response rate of 30%. A comparison of the responses from two sites revealed no significant mean differences for study variables. After checking the data consistency and homogeneity, we retained 568 individual responses for further analysis.

MEASUREMENT AND OPERATIONALIZATION

For all study constructs, we directly adapted the scale items from the literature. The Appendix lists the operational items we used for each construct, and Table 1 provides the univariate statistics for the constructs and the intercorrelations among them.

Table 1 Summary of Statistics and Intercorrelations for the Study Constructs							
	1	2	3	4	5	Mean	s.d.
1. Retention	1					4.80	1.48
2. Work-leisure conflict	-.58*	1				4.24	1.76
3. Role ambiguity	-.58*	.31*	1			2.71	1.27
4. Role conflict	-.61*	.59*	.42*	1		3.94	1.63
5. Role overload	-.49*	.63*	.28*	.63*	1	3.78	1.57
* Correlation is significant at the .01 level (two-tailed).							

RETENTION.

Job satisfaction and retention have been found to be closely related in several studies (Kotzé & Roodt, 2005). Our factor analysis revealed that in certain situations they may in fact be measuring the same things, so we have decided to create a new composition called retention likelihood that incorporates job satisfaction along with intention to quit and desire to remain as a single measure.

WORK-LEISURE CONFLICT.

Previous studies have measured a wide variety of possible effects of work spillover on home life and find that leisure is one of the four most important dimensions (Small & Riley, 1990; Stevens, Kiger & Riley, 2006). Following Small & Riley (1990), we used five items to measure work-leisure conflict.

ROLE AMBIGUITY.

It is defined as "the absence of adequate information which is required in order for persons to accomplish their role in a satisfactory manner" (Senatra, 1980). Since our data are collected from different countries, we adopted the measure from Glazer and Beehr's (2005) study which examined the role stressors on employee attitudes in multi-culture contexts.

ROLE CONFLICT.

It is defined as "the simultaneous occurrence of two (or more) sets of pressures such that compliance with one world make difficult or impossible compliance with the other" (Wolfe &

Snoek, 1962). We also adopted the measure from Glazer and Beehr (2005). According to our factor analysis, one item was dropped from the original measure due to cross loading.

ROLE OVERLOAD.

It is defined as "having too much work to do in the time available" (Beehr et al., 1976). We adopted the scale from Peterson et al.'s (1995) cross nation study on role stress of middle managers.

METHOD OF ANALYSIS

The analytical approach involves measurement assessment of the key constructs and testing the hypothesized model. For the subjective measures, a combination of exploratory factor analysis (EFA) and confirmatory factor analysis (CFA) procedures are used to assess the psychometric properties. We explicitly focused on the evidence for the convergent and discriminant validity of the study constructs.

FINDINGS

MEASUREMENT ANALYSIS

We estimate a fully disaggregated measurement model with the key observed indicator to ensure that the measures correspond only to their hypothesized constructs and evidenced acceptable reliability and validity. A confirmatory factor analysis of the study constructs using AMOS software yielded the following fit statistics: $\chi 2 = 625.03$, d.f. = 307, $p < 0.01$; NFI = 0.94; NNFI (TLI) = 0.96; CFI = 0.97; RMR = 0.05; RMSEA = 0.043 (90% confidence interval = .038 - .048). On statistical, absolute, and relative fit, as well as substantive grounds, the posited measurement model provides a good fit to the data. Table 2 provides further support for the convergent and discriminant validity of the constructs. The estimated loadings for the relationship between individual indicants and their underlying construct are, without exception, large and significant (t-value > 8.0, $p < .01$). In addition, the reliability estimates are large and significant, ranging from .81 to .92, with an average reliability index of .88, which exceeds the conventional .70 criterion. In terms of discriminant validity, the variance extracted not only exceeds the average variance shared but also exceeds or is close to .50, the threshold value that Fornell and Larcker (1981) recommend. The preceding evidence provides robust support for the convergent and discriminant validity of study constructs.

Table 2 Factor Loadings and Measurement Properties of Various Constructs Used						
Construct/Item	Loading[a]	t-Value	Composite Reliability[c]	Variance Extracted[d]	Average Variance Shared[e]	Highest Variance Shared[f]
Retention likelihood			0.89	0.57	0.07	0.12
JS1	0.77	--[b]				
JS2	0.78	18.37				
JS3	0.74	19.90				
ITQ1	0.80	18.19				
ITQ2	0.78	17.76				
DTQR1	0.67	15.65				
Work-leisure conflict			0.88	0.60	0.04	0.06
WLC1	0.86	12.44				
WLC2	0.83	12.21				
WLC3	0.81	12.10				
WLC4	0.82	12.28				
WLC5	0.51	--[b]				
Role ambiguity			0.81	0.43	0.02	0.05
ROAM1	0.55	--[b]				
ROAM2	0.48	10.61				
ROAM3	0.86	13.41				
ROAM4	0.88	13.26				
ROAM5	0.59	10.97				
ROAM6	0.40	8.18				
Role conflict			0.88	0.60	0.08	0.14
ROCO2	0.70	17.67				
ROCO3	0.77	19.67				
ROCO4	0.72	18.07				
ROCO5	0.85	23.15				
ROCO6	0.81	--[b]				
Role overload			0.92	0.70	0.07	0.14
ROOV1	0.80	--[b]				
ROOV2	0.88	28.89				
ROOV3	0.85	21.93				

Table 2 Factor Loadings and Measurement Properties of Various Constructs Used						
Construct/Item	Loading[a]	t-Value	Composite Reliability[c]	Variance Extracted[d]	Average Variance Shared[e]	Highest Variance Shared[f]
ROOV4	0.93	22.52				
ROOV5	0.70	17.54				
Goodness-of-Fit Statistics						
X^2	625.03					
d.f.	307					
p-value	0.00					
NFI	0.94					
NNFI (TLI)	0.96					
CFI	0.97					
GFI	0.93					
AGFI	0.91					
RMR	0.05					
RMSEA	0.043					
(90% Confidence Interval)	0.038-0.048					

[a] The estimates are standardized coefficients (all $p < 0.01$) and t-values from maximum likelihood solution using AMOS 16.0.
[b] The corresponding coefficient was fixed to set the metric of the latent construct.
[c] Estimated composite reliability in line with Fornell and Larcker (1981).
[d] Estimated variance extracted by the corresponding latent construct from its hypothesized indicators in line with Fornell and Larcker (1981).
[e] Average of the variance shared between the corresponding latent construct and all other constructs of study.
[f] The maximum variance shared between the corresponding latent construct and all other constructs of study.

HYPOTHESIZED MODEL ANALYSIS

Our empirical results are summarized in Table 3. Six out of seven hypotheses are supported.

Role ambiguity is negatively related to work-leisure conflict ($\beta = .06$, $p < .05$), which is negatively related to retention ($\beta = -.43$, $p < .01$). Thus, H1 and H2 are supported. In addition, role ambiguity has significant direct effect on retention ($\beta = -.52$, $p < .01$) after controlling for the effect of work-leisure conflict, so H 3 is supported. Based on Shrout and Bolger (2002), the mediation hypothesis is supported if both the antecedent -> intervening and the intervening -> outcome coefficients are significant. Therefore, the results indicate that work-leisure conflict partially mediates the relationship between role ambiguity and retention.

Table 3 Estimated Coefficients for the Hypothesized Model		
	Dependent Variables	
	Work-leisure conflict	Retention
Independent Variables		
Work-leisure conflict	-	-.43 (.06)
Role ambiguity	.06 (.03)	-.52 (.04)
Role conflict	.18 (.03)	-.24 (.04)
Role overload	.26 (.03)	-.04 (.04)
Note: The results reported are unstandardized coefficents followed by standard error in parentheses. Coefficients significant at p = .05 are in bold.		

Similarly, role conflict is positively related to work-leisure conflict (β =.18, $p < .01$), and also directly related to retention (β =-.24, $p < .01$). So H4 and H5 are supported. The results reflect that an increasing emphasis on role conflict reduces retention, and work-leisure conflict partially mediates the relationship between role conflict and retention.

Role overload is positively related to work-leisure conflict (β =.26, $p < .01$), but it doesn't have significant direct effect on retention (β =-.04 $p > .10$). So H6 is supported, but H7 is not supported. The results suggest that work-leisure conflict fully mediates the relationship between role overload and retention.

DISCUSSION

In certain professions like IT, it is not un-common for professionals to work in high stress environments and put in extra hours to meet project deadlines. No wonder that turnover is typically very high in the IT profession. Our research gives better insights into this phenomenon and provides a window into how the various job related stressors and the work-leisure conflict may impact retention likelihood of employees.

Work-leisure conflict has turned out to be an important mediator between job stress and retention likelihood. Its strong inverse relationship with retention likelihood makes it an important factor in retaining employees even beyond the effects of job stressors. Typically work-leisure is part of the broader work-life balance, but we believe that it may be more useful to understand work-leisure thoroughly since when it comes to stress, people typically look for some type of leisure activities to get their mind away from job stress so they can find a way to relax themselves. If employees are not able to find this ‘exit’ from job stress then it increases their chances of leaving the company and find some other work where they can minimize the work-leisure conflict.

When employees have ambiguity in their role, their chances of staying with the company go down dramatically. People generally want to resolve ambiguity so they can perform well at work, especially in some complex fields like IT. This inverse relationship is the most strongly related to retention, relative to other two job stressors, which is consistent with the literature reviewed by Gilba et al. (2008). Moreover, it is roughly independent of the work-leisure conflict although such conflict does slightly mediate the effect of ambiguity on retention.

IT professionals have to deal with conflicts frequently at work due to technology change and technology involved organizational changes, and they often intend to quit jobs if the role conflict can't be handled effectively. However, as our findings show, this situation can get worse when employees also experience work-leisure conflict. In other words, when employees face role conflict and also experience work-leisure conflict, their retention likelihood goes down dramatically. When employees have high role conflict, giving them more leisure time may help with retention, but it will be critical to sooner than later since role conflict has a direct effect on retention likelihood as well.

Role overload appear to spillover the most into work-leisure conflict so that all the effect of role overload on retention likelihood is fully mediated through work-leisure conflict. This is an important finding, since when people are overload with work demands, it does not necessarily mean that they will quit the job. In fact, as our findings reveal, changes of retention likelihood under high role overload will go down only if they also face high work-leisure conflict. Another way to look at it is that organizations can increase work demands (role overload) and not have any significant impact on the retention likelihood as long as they can give employees some opportunity to have leisure outside of work and keep their work-leisure conflict level down.

Overall, we have been able to show that the three role stressors behave differently when it comes to their impact on retention likelihood, and that work-leisure conflict is an important factor that mediates these differences in terms of retaining organizational talents.

PRACTICAL IMPLICATIONS

The importance of job stress on retention has been widely known and acknowledged by executives. At the same time, current business climate requires extra demands from employees that often involve various role stressors. One practical implication of our research is that role ambiguity has much greater impact on retention likelihood than either role conflict or role overload, so organizations should give the highest priority to tackle role ambiguity in stress management.

Second practical implication of our findings is the importance of keeping work-leisure conflict as low as possible even when other role stressors are high. Our findings suggest that much of the impact of role stressors on retention goes through work-leisure conflict and if the management team can find ways to relieve this conflict, they may be able to retain their

employees even though role stressors are high. Being little sensitive to employees' leisure needs outside of work can go a long way in compensating the negative effects of various job stressors.

LIMITATIONS

Prior research has shown that the relationship between role stressors and intention to quit may vary widely depending on the functional role and level of employees within the organizational hierarchy (Cole & Bruch, 2006; Singh, 1998). In our analysis, we have not tested whether the relationship between role stressors, work-leisure conflict and retention likelihood are robust across staff members (front-line workers) and managers, so the findings may not be generalized.

FUTURE RESEARCH

Since work-leisure conflict has shown to play an important role as mediator between role stressors and retention likelihood, it is important to do an extended study to test a much richer work-life conflict model including other related factors in additional to the work-leisure conflict. Also, testing the current model across different functional and hierarchical levels will provide better insights into the generalizability of our findings and if there are differences then a solid understanding of those differences.

AUTHORS' NOTE

Both authors contributed equally**.**

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APPENDIX

Operational Items used to Measure Various Study Constructs

Unless otherwise noted, we measured the following items on a seven-point Likert scale where 1 = "strongly disagree" and 7 = "strongly agree." The items marked with (R) were reversed to keep the consistency with other measures.

Retention Likelihood

Job satisfaction (Mak and Sockel, 2001)

JS1: All in all, I am satisfied with my job.
JS2: In general, I do not like my job. (R)
JS3: In general, I like working here.

Intention to quit (Baroudi, 1985)

ITQ1: I frequently think of quitting my job. (R)

ITQ2: I am planning to search for a new job during the next 12 months. (R)
ITQ3: If I have my own way, I will be working for this organization years from now.

Desire to remain (Steers, 1977)

DTR1: All things considered, I have a desire and intent to remain with this organization.
Work-Leisure Conflict (Small & Riley, 1990)

WLC1: My job makes it difficult for me to enjoy my free time outside of work.
WLC2: The amount of time I spend working interferes with how much free time I have.
WLC3: Worrying about my job makes it hard for me to enjoy myself outside of work.
WLC4: Because I am often tired after work, I don't see friends as much as I would like.
WLC5: My job doesn't affect whether I enjoy my free time outside of work.

Stress

Role Ambiguity (Glazer & Beehr, 2005)

ROAM1: I feel certain about how much authority I have. (R)

ROAM2: I know that I have divided my time properly. (R)
ROAM3: I know what my responsibilities are. (R)
ROAM4: I know exactly what is expected of me. (R)
ROAM5: I know what the critical factor is in getting promoted. (R)
ROAM6: I know how I should handle my free time on the job. (R)
Role Conflict (Glazer & Beehr, 2005)

ROCO1: I have to do things that should be done differently.
ROCO2: I work under incompatible policies and guidelines.
ROCO3: I receive an assignment without the resources to complete it.
ROCO4: I have to buck (bend) a rule or policy in order to carry out an assignment.
ROCO5: I receive incompatible requests from two or more people.
ROCO6: I have to work under vague directives or orders.
Role Overload (Peterson et al., 1995)

ROOV1: There is a need to reduce some parts of my role.
ROOV2: I feel overburdened in my role.
ROOV3: I have been given too much responsibility.
ROOV4: My workload is too heavy.
ROOV5: The amount of work I have to do interferes with the quality I want to maintain.

GSS ANONYMITY EFFECTS ON SMALL GROUP BEHAVIOR

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ABSTRACT

Professionals and managers participated in a field experiment to determine the effects of Group Support System (GSS) anonymity and status on group productivity and satisfaction. In GSS sessions, they discussed ways to solve the problem of insurance fraud within their industry. Groups of four and five members interacted either with or without anonymity, and either with equal status or unequal status. Anonymous groups generated more total comments, more unique ideas, and more ideas of higher rarity than did identified groups. Equal status group members were more satisfied than unequal status members.

INTRODUCTION

The study of Group Support Systems (GSS) as an aid to group decision-making in organizations is important to organizational researchers for practical and scientific reasons (DeSanctis and Gallupe, 1987; Huber et al., 1993). GSS are a promising vehicle for better managing groups. When meeting as a group, group members bring with them external status characteristics, which are derived from their formal position within an organization's hierarchy, personal reputation, community or social status (age, sex, or race) (Berger et al., 1972). Some common problems experienced by decision-making groups include the extreme influence exerted by high-status members, the lack of acknowledgment of low-status members' ideas, and a low tolerance exhibited toward minority or controversial opinions (DeSanctis and Gallupe, 1987). Group members with low external status characteristics have difficulty achieving influence over group decisions (Ridgeway, 1982). Some group members are often reluctant to contribute, because of their shyness, low status, and/or the controversial ideas being discussed (DeSanctis and Gallupe, 1987).

In a GSS environment, anonymity plays an important role in enabling group members to better participate, making group meetings more productive (see for a review, Valacich et al., 1992a). The conceptual framework of GSS anonymity (Valacich et al., 1992a) defines anonymity as the extent to which group members' contributions are identifiable to the other group members or to others outside the group.

The theoretical model of GSS (Dennis et al,, 1988) describes several variables that affect group process and outcome, among them are GSS anonymity and group member status. The purpose of this research was to study how the anonymity component of a GSS and group member status interact to influence group productivity and group member satisfaction.

RESEARCH ON GSS ANONYMITY

Many researchers studied GSS anonymity. Much of this research suggests the effects of GSS anonymity are positive (see, for example, Beauclair, 1987; Connolly et al., 1990; DeSanctis and Gallupe, 1987; Jessup, 1989; Nunamaker et al., 1987; Nunamaker et al., 1988; Valacich et al., 1992a). Anonymity is believed to create an environment in which group members participate equally, vote their conscience, and participate more often than they might in a non-computerized environment where their contributions are more easily identified. With the anonymity component of a GSS, the fear of embarrassment, social disapproval, and the sanction of an ill-received remark may be greatly reduced. Anonymity thus enables group members to speak freely and contribute ideas openly and honestly without fear of direct reprisals, especially when participants feel concerned about their personal or professional security. In addition, anonymity promotes the honest, objective evaluation of contributions based solely on the merits of ideas and not authors. Consequently, participants should generate and better evaluate more ideas, and make better decisions.

Conversely, a fair amount of research on GSS anonymity suggests that the effects of anonymity may be negative (see, for example, DeSanctis and Gallupe, 1987; Jessup, 1989; Jessup et al., 1990b; Nunamaker et al., 1988). Anonymity may enable participants to be overly caustic in their evaluations of others, and more blunt and assertive in their comments, which may heighten conflict within the group. Anonymity may afford a group member an opportunity to hide, masking the individual's effort or lack of effort. As a result, participants may loaf and let others do the work. In addition, anonymity may filter out some communication and cause some political information often obtained in meetings to be lost.

An explanation for these differing arguments can be seen when one compares the results of laboratory experiments of GSS anonymity with field studies. The results from laboratory experiments of GSS anonymity are mixed. In some laboratory experiments, researchers found effects from GSS anonymity. For example, several researchers found anonymous group members generated more solution clarifications, critical and total comments, and questions about solutions than did groups working under identified conditions. Anonymous group members using a GSS were more critical, probing, and more likely to embellish an idea than identified group members using a GSS. In one of the three studies, groups interacting anonymously also generated more unique, goal-directed ideas than did groups interacting without anonymity (Connolly et al., 1990; Jessup et al., 1990a; Jessup et al., 1991).

In other laboratory experiments, the researchers found no effects for GSS anonymity (see, for example, Beauclair, 1989; Dennis, 1991; George et al., 1990; Valacich et al., 1992b). In one study (Beauclair, 1989), although the subjects felt anonymity allowed them to effectively interact and reveal their true feelings, their actual performance did not match this perceived satisfaction. The lack of results suggested that a GSS does not appear useful for groups without a vested interest in the task, an established history, or an inequitable hierarchy that might create a situation in which the anonymity component of a GSS would be needed.

The mixed findings from these laboratory experiments of GSS anonymity are in contrast with field studies of GSS anonymity (see, for example, Nunamaker et al., 1987; Nunamaker et al., 1988; Dennis, 1991). These researchers studied users of GSS in a variety of organizations, at various levels within these organizations, involving a variety of tasks and group sizes. The methods used in these studies included participant observations, structured observations, and pre- and post-session questionnaires. In these field studies of GSS, researchers found stronger, more positive effects from GSS anonymity than did researchers using laboratory studies.

Field study researchers reported that because of GSS anonymity, group members appeared to express their true feelings without fear of social disapproval (Nunamaker et al., 1987). Group members using GSS reported that anonymity was an important, if not the most important, GSS contribution (Dennis, 1991). Group members also reported that anonymity encouraged open and honest discussions, and they perceived that anonymity reduced organizational politics (Dennis, 1991). Group members also perceived that anonymity encouraged more participation, particularly from those with lower status (Dennis, 1991). The researchers concluded that GSS anonymity appeared to neutralize the effects of an authority hierarchy in the group (Nunamaker et al., 1987) and that anonymity was a positive factor in encouraging broad-based participation (Nunamaker et al., 1988). In one study (Nunamaker et al., 1988), the researchers also suggested that anonymity might heighten group conflict, because members became more blunt, assertive, and not as polite as in personal interactions.

UNDERSTANDING ANONYMITY'S EFFECTS

It appears that, depending on the setting, the effects of GSS anonymity can be positive, negative, or negligible. Results from some laboratory experiments suggest a GSS does not appear useful for groups without a vested interest in the task (Jessup, 1989), an established history, or an inequitable hierarchy that might create a situation in which the anonymity component of a GSS would be needed (Beauclair, 1989). One field study (Dennis, 1991) reported that for members of peer groups anonymity was less important than for members of groups of superiors and subordinates with formal power and status differences.

The richness and reality of the field setting appear to provide the environment in which GSS anonymity is more useful. These field environments tend to be places where individuals

have a more vested interest in the task at hand, either because of some personal or professional stake in the task. Consequently, they feel more compelled to contribute. In addition, the threat of repercussions for ill-received contributions to the group is greater. The potential disadvantages because of these ill-received contributions are stronger and more salient. Further, it appears that within the group the status of group members is important in determining whether GSS anonymity is more necessary and important. In the laboratory experiments, group members were friends, acquaintances, or strangers; whereas, in the field studies, groups normally contained a distinct, natural hierarchy of power and authority.

Some researchers studied the status construct in GSS experiments (see, for example, Lim et al., 1990; Tan et al., 1993), but in these laboratory experiments status was defined as "influence," operationalized as an artifact of group process, and treated as a dependent variable.

HYPOTHESES

In groups with unequal status, low-status members will have fewer opportunities to interact, be less likely to have their suggestions evaluated by the group, and have less influence on group decision-making. Status generalization is the process where external status characteristics order the internal status of a group and create an interaction disability for low-status members (Ridgeway, 1982). This process occurs whether or not the external status characteristics are related to the group task (Berger et al., 1972). To reduce this disability requires techniques for overcoming the status generalization process (Ridgeway, 1982). We predict that GSS anonymity will overcome the status generalization process in groups with unequal members.

As argued in laboratory experiments and field studies on GSS anonymity, anonymity should allow more ideas to be generated during a meeting, because group members with low-status would contribute ideas more freely and openly. Anonymity should also promote the honest and objective evaluation of an idea based on the merit of the idea and not the contributor, because group members would more freely evaluate and criticize other members' ideas (Connolly et al., 1990; Jessup et al., 1990a; Jessup et al., 1991; Valacich et al., 1991). In short, GSS anonymity should be most helpful under the conditions of unequal status described above (Beauclair, 1989; Dennis, 1991; Jessup, 1989; Nunamaker et al., 1987; Nunamaker et al., 1988). Further evidence is provided by the results of two laboratory experiments (Lim et al., 1990; Tan et al., 1993), which showed that use of a GSS dampened status influence within groups.

In groups where the members are of equal status, when group members make contributions or criticize ideas of other members, they do not feel strongly restrained, nor do they severely fear disapprovals. With or without anonymity, group members should be able to contribute and criticize ideas more freely and more honestly. Anonymity should have minimal or

negligible effect on group interaction or output (Beauclair, 1989; Dennis, 1991). We thus hypothesize:

H_1: *Groups whose members are unequal in status and anonymous will generate more total comments and unique ideas, more ideas of higher rarity, and more critical comments than will groups whose members are unequal in status and identified.*

H_2: *Groups whose members are equal in status will generate more total comments and unique ideas, more ideas of higher rarity, and more critical comments than will groups whose members are unequal in status.*

H_3: *Groups interacting under anonymity will generate more total comments and unique ideas, more ideas of higher rarity, and more critical comments than will groups interacting without anonymity.*

In field studies and laboratory experiments of GSS, participants are generally satisfied with the anonymity component. We believe that in our field experiment group members unequal in status and anonymous should be more satisfied than group members unequal in status and identified. Anonymity should reduce the fear of embarrassment, disapproval, or sanction of an ill-received remark in groups with unequal status. Group members equal in status should be more satisfied than those that are unequal in status, because group members with equal status will not feel strongly restrained or severely fear disapprovals. Anonymous group members should be more satisfied than identified group members, because anonymous group members would be able to contribute ideas more freely and openly than would identified group members. Therefore, we hypothesize:

H_4: *Group members unequal in status and anonymous will be more satisfied than will group members unequal in status and identified.*

H_5: *Group members equal in status will be more satisfied than will group members unequal in status.*

H_6: *Group members interacting under anonymity will be more satisfied than will group members interacting without anonymity.*

RESEARCH DESIGN

An empirical, quantitative laboratory experiment, or a qualitative field study design, would each provide its unique disadvantages. A need exists for a controlled field experiment on GSS anonymity and status for which the precision and control of the laboratory are used with real participants, with real status differences, performing a task of importance and relevance to them. We can then see how the experimental findings from the field match with the mixed findings from the laboratory, whether positive or negative. We thus chose to conduct a hypothesis-testing, field experiment (Kerlinger, 1986) using a 2 X 2 factorial design (crossing anonymity with group member status) with random assignment and equivalent groups.

Status - Group members were either equal in status or unequal in status. For this study, the most easily measured external status characteristic was the position of the subject in the organization's hierarchy of reporting and responsibility. Thus, we operationalized group member status such that members of equal status had positions at the same level of reporting and responsibility within the organization. Members of unequal status had positions at different levels of reporting and responsibility within the organization.

Before the experiment began, subjects completed a questionnaire in which they answered questions related to their position within the organization. The authors used the questionnaires to assign subjects to groups in which all members were equal in status, or to groups in which one or more of the members had a higher level of status within the organization. For groups with a higher level of status, 40% contained one manager, 40% had two, and the remaining 20% contained three managers. 40% of the groups with a higher level of status included two levels of managers. To make the status manipulation stronger, as suggested by pilot testing, we asked the participants to stand up at the beginning of the sessions and state their name, department, and job title.

Nearly all the group members knew each other from working together prior to the study. In addition, fifty percent of the groups contained all members currently from the same department; 22% had three out of four, and 28% contained two out of four members from the same department. With the above manipulations, we believed we created a structure where status mattered.

Anonymity - We used the following definition of GSS anonymity: the extent to which group members' contributions to the group are identifiable to the other group members or to others outside the group (Valacich et al., 1992a). While using the GSS, group members were either anonymous or identified. The GSS software was set such that the group members in the anonymous condition submitted their ideas and comments without identifying themselves. In the identified condition, group members added their first name, and the first initial of their last name, to the beginning of all ideas and comments submitted during the GSS session.

Following a widely used methodology (Connolly et al., 1990; Jessup et al., 1990a; Jessup et al., 1991), there were five dependent variables in this experiment: total number of comments

generated, number of unique ideas generated, rarity of ideas generated, number of critical comments, and satisfaction with using a GSS. To operationalize the first four dependent variables, we used a content coding scheme (Connolly et al., 1990), which consistently produced high rates of reliability. Given the consistency and high reliability of this process, we did not compute additional reliability measures for our use. Two raters analyzed comments each group produced during the GSS session and then independently classified each comment into one of several categories, such as proposed a solution, made a critical remark, and so on. The raters then compared ratings and came to consensus on any differences.

Unique ideas consisted of proposed solutions, minus redundancies and frivolous ideas (Jessup, 1989). To measure rarity of ideas generated, we first counted the number of times each idea appeared among all groups. To compute rarity, we then used the reciprocal of the count for each idea. For example, an idea proposed only once produced a rarity score of 1.0, while the more common ideas generated scores approaching zero (Jessup, 1989). A critical comment was an expression of opposition to a proposal with, or without, evidence or argument.

We also followed a highly reliable methodology (Connolly et al., 1990; Jessup et al., 1990a; Jessup et al., 1990b) to measure the fifth dependent variable, satisfaction with using a GSS, by using the same post-experimental questionnaire. Each member answered 15 questions on a five- point Likert scale. One question measured overall satisfaction. Other questions measured a group member's perception of the meeting process. To determine the average satisfaction rating, the authors summed the values of the fifteen satisfaction-related questions for each group member (Easton et al., 1989).

For statistical analysis of the relationships among the dependent and independent variables, we used MANOVA to analyze the four dependent measures of group output: total number of comments generated, number of unique ideas generated, rarity of ideas generated, and number of critical comments. We used ANOVA to analyze satisfaction with using a GSS, the group member dependent variable.

The post-experimental questionnaire contained questions used to check the anonymity and status manipulations. Two questions used to check the anonymity manipulation were, “Was it possible to trace comments to people who proposed them?” and “Were other participants in your group able to trace comments to people who proposed them?”. Participants answered each question with either “Yes = 3, Don’t Know = 2, or No 1” (Connolly et al., 1990).

Three questions used to check the status manipulation were, “Were members of your group equal in status, as related to their job descriptions at work?”, “Did you feel pressured by another group member(s) with higher status?”, and “Were you afraid to express your ideas, because of a higher status member(s) in your group?”. Participants answered each question with either “Yes = 3, Don’t Know = 2, or No = 1”.

We held constant two variables for all groups during the experiment: the task and group size. The authors selected the insurance fraud task, an idea generating task, defined as a creativity task (task type two) involving generating ideas or alternatives (McGrath, 1984). *Best’s*

Review, and the Insurance Information Institute, described insurance fraud as one of the most important issues confronting the insurance industry. Subjects in this study were managers and professional employees of an insurance company. These insurance company employees dealt with this issue on a daily basis. All had thoughts and ideas on this major issue confronting their industry. Group size varied between four and five members. Following a common practice for GSS experiments, we invited five potential participants per session in order to guarantee that at least four showed up.

EXPERIMENTAL SETTING AND PROCEDURES

All sessions took place in the personal computer (PC) laboratory. As part of the meeting room facility, the PC laboratory is a normal setting for groups to perform tasks, such as groups meeting to receive training on PC software. This setting satisfies the definition for a field experiment (Kerlinger, 1986, p. 372). The PC laboratory consisted of six personal computers arranged classroom style on two rows of tables. The authors inserted privacy panels between the six PCs and between the two rows of tables. A participant was not able to see other participants' personal computer screens or keyboards. Whenever possible, participants sat at alternating PC's to minimize distracting one another during a session. The PC laboratory contained no windows, which further prevented distractions.

A total of 75 subjects in 18 groups participated in this experiment. All subjects were employees, who were either managers or professionals. The authors invited potential participants from departments related to selling, underwriting, claim, credit, audit, policy processing, internal audit, and education.

Subjects completed copies of a pre-experimental questionnaire. The authors used the questionnaires to determine participants' levels of computer literacy, willingness to participate, and times available to participate, as well as other personal attributes (Beauclair, 1987). The authors used the questionnaires to assign subjects randomly to groups in which all members were equal in status, or to groups in which one or more of the members had a higher level of status within the organization. The authors assigned equal and unequal status groups randomly to groups in which all members were anonymous or identified.

To ensure uniformity during the sessions, the authors conducted all sessions using a standard script. Each subject received a copy of the standard script to follow as the authors read aloud the set of instructions. At the beginning of the session, the subjects received training on how to use the hardware and GSS software. They practiced using the hardware and software by performing an idea generating warm-up task. We then introduced the insurance fraud task, encouraged the subjects to generate as many ideas as possible to solve the problem of fraud in the insurance industry, and emphasized that the case should not be discussed out loud. The instructions stated that a panel of two raters, who would separate the ideas from other comments

and assign a quality rating to the ideas, would review ideas and comments. A thirty minute brainstorming session followed, during which time the subjects used the GSS to generate as many solutions to the task as possible. Subjects completed a post-experimental questionnaire, which the authors used to assess subjects' reactions to the session. We then debriefed and released the subjects.

We used GSS Brainwriting software from VisionQuest™, version 2.1, by Collaborative Technologies Corporation. The hardware consisted of five IBM compatible personal computers connected to an IBM PC server via a token-ring local area network (LAN).

RESULTS

A total of 75 subjects in 18 groups participated in the experiment. The average age of the subjects was 38 years. 61% of the subjects were female, and 39% of the subjects were male. The subjects were either managers or professional employees, which is consistent with other reported case and field studies (Fjermestad and Hiltz, 2000). 24% of the subjects were managers, and 76% were professional employees. Table 1 shows the relationship between the number of groups and subjects, and the independent variables anonymity and status.

Table 1: Group and Subjects by Independent Variables

Anonymity	Status	
Anonymous	Equal	Unequal
Number of Groups	4	5
Number of Subjects	17	21
Identified		
Number of Groups	4	5
Number of Subjects	16	21

From the post-experimental questionnaire, the authors used subjects' responses to questions to determine how important the subjects thought the insurance fraud task was. Table 2 contains means and standard deviations for each of the three task importance questions.

Means for each of the three task importance questions were all well above the mid-point on the five-point measurement scale. The results show that the insurance fraud task was important to subjects in all conditions.

Table 2: Means and Standard Deviations for Task Importance Questions		
	Mean	St.dev
Important Problem?	4.733	0.577
Important to Generate Solutions?	4.520	0.665
Useful Ideas to Solve Problem?	3.967	0.832

To test the subjects understanding of manipulations of anonymity and status, the authors used subjects' responses to questions in the post-experimental questionnaire. Responses to the anonymity manipulation questions showed that all identified subjects understood the manipulation. 100% of identified subjects stated it was possible to trace comments to people who proposed them, and 95% stated others within their group were able to trace comments to people who proposed them.

The majority of anonymous subjects understood the anonymity manipulation. 76% of anonymous subjects stated it was not possible to trace comments to people who proposed them. However, anonymous subjects were unsure if others within their group were able to trace comments to people who proposed them, because 82% answered 'don't know' to this question.

Responses to the status manipulation question showed that almost all of the equal status subjects understood the manipulation. 97% of the equal status subjects answered "yes" to the question, "Were members of your group equal in status, as related to their job description at work?" The majority of unequal status subjects, 55%, answered "no" to the same question, indicating a weaker manipulation among unequal status subjects.

As previously reported (Connolly et al., 1990), the inter-rater reliability of the content coding scheme is consistently in the 94% to 95% range of rater agreement. We deemed a separate inter-rater reliability for this study to not be necessary given our numerous previous experiences with the content coding scheme and the fact we followed the content coding scheme to the letter. We calculated the reliability coefficient for our use of the content coding scheme. We found it to be reliable (Alpha = .8943).

Tables 3 and 4 contain summaries of results for the independent and dependent variables. Anonymous groups generated more total comments ($F = 4.289$, $P = 0.057$), more unique ideas ($F = 4.248$, $P = 0.058$), and more ideas of higher rarity ($F = 5.560$, $P = 0.033$) than did identified groups. The pattern supports hypothesis H3. Equal status group members were more satisfied than were unequal status group members ($F = 5.560$, $P = 0.033$, 1,71 d.f.), which supports hypothesis H5. There was no evidence to support the following research hypotheses: H1, H2, H4, and H6.

Table 3: Results for the Independent and Dependent Variables				
	Equal Status			
	Anonymous		Identified	
Measure	Mean	St.dev	Mean	St.dev
Total Number of Comments	52.75	25.42	36.25	6.24
Number of Unique Ideas	35.50	18.45	24.75	1.26
Number of Higher Rarity Ideas	21.59	15.30	12.28	2.98
Critical Comments	1.50	1.29	0.75	0.96
Satisfaction	57.77	9.61	59.38	7.73

Table 4: Results for the Independent and Dependent Variables (continued)					
	Unequal Status				
	Anonymous		dentified		Sign Level
Measure	Mean	St.dev	Mean	St.dev	S A X
Total Number of Comments	64.80	22.62	42.40	20.27	--- * ---
Number of Unique Ideas	44.60	15.50	29.00	13.17	--- * ---
umber of Higher Rarity Ideas	25.27	9.89	13.69	6.05	--- ** ---
Critical Comments	3.60	5.32	0.40	0.89	--- --- ---
Satisfaction	53.90	9.64	53.48	9.09	** --- ---
For significance, the S column indicates significant main effects for status, the A column indicates significant main effects for anonymity, and the X column indicates a significant interaction effect. **p < .05; *p < .10.					

DISCUSSION

In this field experiment, anonymous groups generated more total comments, more unique ideas, and more ideas of higher rarity than did identified groups, which is consistent with earlier GSS laboratory experiments (Jessup et al., 1990a; Connolly et al., 1990; Jessup et al., 1991). These results also fit with those of laboratory experiments where there were no effects of GSS anonymity (see, for example, Beauclair, 1989; Jessup, 1989). The researchers in these other studies explained there were no findings because there was little or no reason for anonymity to be important in these environments.

Replicating the results of the laboratory experiments on GSS anonymity by Jessup and his colleagues is important given this study was a true field experiment in a business organization, using managers and professionals as subjects and having them complete a non-contrived task. In comparing early experimental and field studies involving GSS, findings from field studies should not be generalized to use of GSS in experimental settings, and vice versa (Dennis et al,, 1990-1991). The parallel results from this field experiment of anonymity are a step in the direction of overcoming shortcomings of early field and experimental studies and drawing together field and laboratory studies (Dennis et al,, 1990-1991).

There were no statistically significant effects for status on number of total comments, number of unique ideas, number of higher rarity ideas, or critical comments. It may be that status is important, but maybe it was not operationalized well enough in this experiment. Perhaps we did not manipulate status strongly enough, or provide a task for which status is important. Alternatively, perhaps the instructions for manipulating status were not perceived by subjects as the authors intended. As the results of the manipulation checks show, a very high percentage of subjects in the equal status condition reported "yes" to members in their group were of equal status. Conversely, only 55% of the group members in the unequal status condition answered "no" to the same question, indicating a weaker manipulation among unequal status subjects. We believe that the manipulation worked adequately. The procedure we used to manipulate status was quite straightforward. Subjects were paying attention when we had them introduce themselves to each other out loud.

To test whether or not our measure of status was adequate, we conducted a post-hoc analysis of status using available data to measure other aspects of status, which were identified in the literature. We also operationalized status with more sensitive, continuous variables rather than as a single binary variable. To measure the level of status in each group, we used the following alternative formulas:

1. Type of manager: based upon the level of responsibility and reporting within the organization's managerial hierarchy; unit manager = 1, manager = 2, and director = 3; summed the type(s) of manager present per session; groups ranged from 0 to 7.

2. Number of managers: based upon the number of managers present per session; each manager given a value of 1; summed the number of managers present per session; groups ranged from 0 to 3.

3. Age of managers: based upon managers' actual ages; summed ages of managers present per session; groups ranged from 0 to 134.

4. Experience of managers: based upon number of years of managers' working experience; summed experience of managers present per session; groups ranged from 0 to 50.

5. Gender of managers: based on managers' gender; assigned 1 to female manager and 2 to male manager; summed assigned values for gender of managers per session; groups ranged from 0 to 6.

6. Combined status: sum total of all values for continuous status measures.

We repeated the analysis of variance for these new status variations and found the pattern of our results did not change, and the results matched our initial approach.

One other explanation for the original, insignificant results for status is that status isn't the key construct. Perhaps other factors operating within a group would more strongly cause certain members to be afraid to contribute. It may be as simple as an overpowering group member who would ridicule others for their ideas, regardless of that person's status within the organization. Alternatively, it may be that, at the individual level, self-confidence or personal security are more likely to cause a person to be afraid to contribute, regardless of status. Given the compelling arguments for status as an important variable in this setting, and given that status is likely to correlate with these other variables, this explanation is not as likely.

A more plausible explanation for the insignificant output results is that while subjects could clearly see members of their group were from a different level in the organization, employees from this organization do not believe this constitutes a difference in "status." Further, it may be professionals and managers in this study were too democratic for status differences to mean much, and/or group members were too comfortable working with first level managers, with whom they may have developed a rapport. Our prior experience with the employees of this organization, which is substantial, suggests such is the case.

Further evidence these groups were civil is provided by the analysis of critical comments. Contrary to our hypothesis, anonymous groups were not more critical than identified groups, which is not consistent with prior empirical studies where anonymous groups were more critical than identified groups (Jessup et al., 1990a; Jessup et al., 1991; Valacich et al., 1991). In addition, the number of critical comments was generally low for all groups. The business professionals and managers participating in this field experiment were less critical than were subjects from prior laboratory experiments with student subjects. Student subjects are generally younger, meet as a group one time for the research experiment, and then see little or nothing of each other after the session. The business professionals and managers in this experiment were less critical because of their organizational culture, professional maturity, and because they knew they would work with each other after the session.

Some final evidence of the civility of these participants is provided by the results for the satisfaction measures. Contrary to our hypothesis, anonymous group members were not more satisfied than were identified group members. Generally, all participants were relatively satisfied with the experience. Apparently, the interaction was not of a type where the group members would be more satisfied under anonymity.

Interestingly, there was a statistically significant effect for status on group member satisfaction. Group members equal in status were more satisfied than group members unequal in status. To better understand why, we analyzed responses to each question on the post-experimental questionnaire. We found that the responses of group members equal in status were significantly higher (significant at the .05 level) than were the responses of the group members unequal in status on the following items: the participation in the discussion was evenly distributed, the behavior of the group was goal directed, the interpersonal relationships among the participants were healthy, participants dealt systematically with the issues, participants initiated discussion on relevant issues, and members were satisfied with the quality of the group's solutions. While the members of this organization may in fact not be influenced to a great degree by organizational status in terms of their actual output in the GSS sessions, the status manipulation worked. There were significant differences, at least in terms of perceptions, between equal and unequal status groups.

IMPLICATIONS

The results of this field experiment confirm the quantitative finding from laboratory experiments, and the qualitative finding from field studies, that GSS anonymity is useful. In this field experiment, while performing an idea generating task in a laboratory setting, anonymous groups of business professionals and managers generated more total comments, unique ideas, and ideas of higher rarity than did identified groups. This experiment suggests we may need to either think differently about the status construct and/or work toward a better operationalization of status in experimental settings. While there was no significant effect for status on real output, groups equal in status were more satisfied than were groups unequal in status.

One explanation is we chose the right construct and manipulated it correctly. Compelling evidence in the literature suggests an organizationally based status variable is important. In addition, our manipulation of status was straightforward. The results of the manipulation check suggest that it was understood by most subjects. Further, the results of our post-hoc analysis using alternative status measures matched the results of our original analysis. The implication is, for settings like the one studied here, organizationally based status may not be important in terms of its effects on real group output, though being in equal status groups made participants feel better about their session. Further, status differences do not seem to be important, in terms of real

output, for groups like ours that are mature, professional business people with real, lasting relationships with each other that transcend the experiment.

Another avenue for exploration is that we chose the right construct, but we did not operationalize it well. Our manipulation of status, while straightforward to subjects, may not have been strong enough. Perhaps we needed to include individuals with a higher level of responsibility in an organization than managers. For example, including senior and executive vice presidents, or selectively choosing managers based on their leadership styles, may strengthen the status manipulation. Alternatively, we may have chosen a more sensitive task to make status differences more important. A task that would evoke different preferences between status levels with direct implications for members (e.g., bonus allocations, promotion policies, etc.) may be more likely to surface status effects. In future field experiments of this type, researchers might also increase the number of groups to determine if a larger sample size would produce a statistically significant result for status.

It is possible organizationally based status is not as important as other phenomena. Perhaps status based on seniority or expertise is more important. Alternatively, anonymity may be more important for individuals who are afraid to contribute, regardless of the setting. In such a case, we should study individual level phenomena, such as self-confidence or dominance versus submissiveness. Researchers need to isolate these other factors and manipulate them along with anonymity to determine if they, rather than organizationally based status, are the real factors keeping some group members from contributing.

While this study suffered the small sample size inherent in field experimentation, one thing is clear. It was useful to draw from the results of quantitative laboratory experiments and qualitative field studies on GSS, and then build theory to be tested in a field experiment. Field experiments are difficult and costly, but they help to integrate and validate these other types of research. In this field experiment we attempted, as best we could, to simultaneously maximize the three conflicting research "desiderata" (McGrath, 1990) - generalizability, precision, and realism.

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TESTING A MODERATOR-TYPE RESEARCH MODEL ON THE USE OF MOBILE PHONE

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ABSTRACT

Individual adoption of technology has been studied extensively in the workplace (Brown & Venkatesh, 2005). Far less attention has been paid to adoption of technology in the household (Brown & Venkatesh, 2005). Obviously, mobile phone is now integrated into our daily life. Indeed, according to the more recent forecast of Gartner Research, 1.22 billion of mobile phones have been sold throughout the world in 2008, a 6 percent increase over 2007 sales (Gartner Newsroom, 2008). And, as the tendency is showing up, mobile phone use will be still increasing in the future. The purpose of this study is then to investigate who really are the mobile phone users and what are the determining factors who make such they are using a mobile phone? On the basis of the moderator-type research model developed by Brown and Venkatesh (2005) to verify the determining factors in intention to adopt a computer in household by American people, this study examines the determining factors in the use of mobile phone in household by Canadian people. Data were gathered from 327 Atlantic Canadian people who own a mobile phone. Data analysis was performed using the structural equation modeling software Partial Least Squares (PLS). The results revealed that half of the variables examined in the study showed to be determining factors in the use of mobile phone by people in household.

INTRODUCTION

Since numerous years, mobile phone is used for different professional purposes, particularly by senior managers in the workplace. And this technology is more and more used in the workplace since mobile applications have been integrated to actual enterprise business strategies. Individual adoption of technology has been studied extensively in the workplace (Brown & Venkatesh, 2005). Far less attention has been paid to adoption of technology in the household (Brown & Venkatesh, 2005). Obviously, mobile phone is now integrated into our daily life. According to the more recent forecast of Gartner Research, 1.22 billion of mobile phones have been sold throughout the world in 2008, a 6 percent increase over 2007 sales (Gartner Newsroom, 2008). And, as the tendency is showing up, mobile phone use will be still increasing in the future. The purpose of this study is then to investigate who really are the users of a mobile phone and what are the determining factors who make such that they are using a mobile phone?

Table 1: Related Literature Survey (adapted from Isiklar & Büyüközhan, 2007, p. 267; and updated)	
Research Area	***References***
Mobile phone diffusion and its impacts on people's daily life.	LaRose (1989) Kwon & Chidambaram (2000) Botelho & Costa Pinto (2004) Funk (2005) Andonova (2006) Centrone et al. (2007) Ehlen & Ehlen (2007) Fillion & Berthelot (2007) Nasar et al. (2007) Fillion & Le Dinh (2008) Kurniawan (2008)
Mobile phone ownership and usage.	LaRose (1989) Kwon & Chidambaram (2000) Palen et al. (2000) Aoki & Downes (2003) Selwyn (2003) Davie et al. (2004) Mazzoni et al. (2007) Peters et al. (2007) Tucker et al. (2007) Sohn & Kim (2008)
Mobile phone ownership and usage from a behavioural and psychological perspective.	Karjaluoto et al. (2003) Wilska (2003) Davie et al. (2004) Liljander et al. (2007) White et al. (2007) Butt & Phillips (2008)
Effects on human health and daily activities.	Repacholi (2001) Salvucci & Macuga (2002) Weinberger & Richter (2002) Sullman & Baas (2004) Treffner & Barrett (2004) Westerman & Hocking (2004) Balik et al. (2005) Balikci et al. (2005) Eby et al. (2006) Rosenbloom (2006) Törnros & Bolling (2006)
Evaluation and design of mobile phone features for user interface and user satisfaction.	Chuang et al. (2001) Chen et al. (2003) Han & Wong (2003) Chae & Kim (2004) Han et al. (2004) Lee et al. (2006)
Analytical evaluations of mobile phone-related observations.	Tam & Tummala (2001) Campbell & Russo (2003) Han & Wong (2003) Wang & Sung (2003) Lai et al. (2006)

Few studies have been conducted until now which investigate the intention to adopt a mobile phone by people in household (in the case of those who do not yet own a mobile phone) or the use of mobile phone in the everyday life of people in household (in the case of those who own a mobile phone). Yet we can easily see that mobile phone is actually completely transforming the ways of communication of people around the world. It is therefore crucial to more deeply examine the determining factors in the use of mobile phone by people in household. This is the aim of the present study. The related literature on the actual research area of mobile phone is summarized in Table 1.

In addition to the summary of literature on the actual research area of mobile phone presented in Table 1, other researchers have identified some factors which may increase the use of mobile phone by people in household. For example, in a large study conducted in 43 countries of the world, Kauffman and Techatassanasoontorn (2005) noted a faster increase in the use of mobile phone in countries having a more developed telecommunications infrastructure, being more competitive on the wireless market, and having lower wireless network access costs and less standards regarding the wireless technology. And a study involving 208 users by Wei (2008) showed that different motivations predict diverse uses of mobile phone. According to the Wei's findings, mobile phone establishes a bridge between interpersonal communication and mass communication.

As we can see in the summary of literature related to mobile phone presented above, few studies until now examined the determining factors in the use of mobile phone by people in household. Thus, the present study brings an important contribution to fill this gap as it allows a better understanding of the impacts of mobile phone usage into people's daily life. It focuses on the following two research questions: (1) Who are the buyers of mobile phone for household use? (2) What are the determining factors in the use of mobile phone by people in household?

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, the theoretical approach which guides the study is developed; second, the methodology followed to conduct the study is described; finally, the results of the study are reported and discussed.

THEORETICAL APPROACH

This study is based on the theoretical foundations developed by Venkatesh and Brown (2001) to investigate the factors driving personal computer adoption in American homes as well as those developed by Brown and Venkatesh (2005) to verify the determining factors in intention to adopt a personal computer in household by American people. In fact, Brown and Venkatesh (2005) performed the first quantitative test of the recently developed model of adoption of

technology in households (MATH) and they proposed and tested a theoretical extension of MATH integrating some demographic characteristics varying across different life cycle stages as moderating variables. With the exception of behavioural intention (we included user satisfaction instead given people investigated in this study own a mobile phone), all the variables proposed and tested by Brown and Venkatesh (2005) are used in this study. And we added two new variables in order to verify whether people are using mobile phone for security and mobility. The resulting theoretical research model is depicted in Figure 1.

Figure 1
Theoretical Research Model

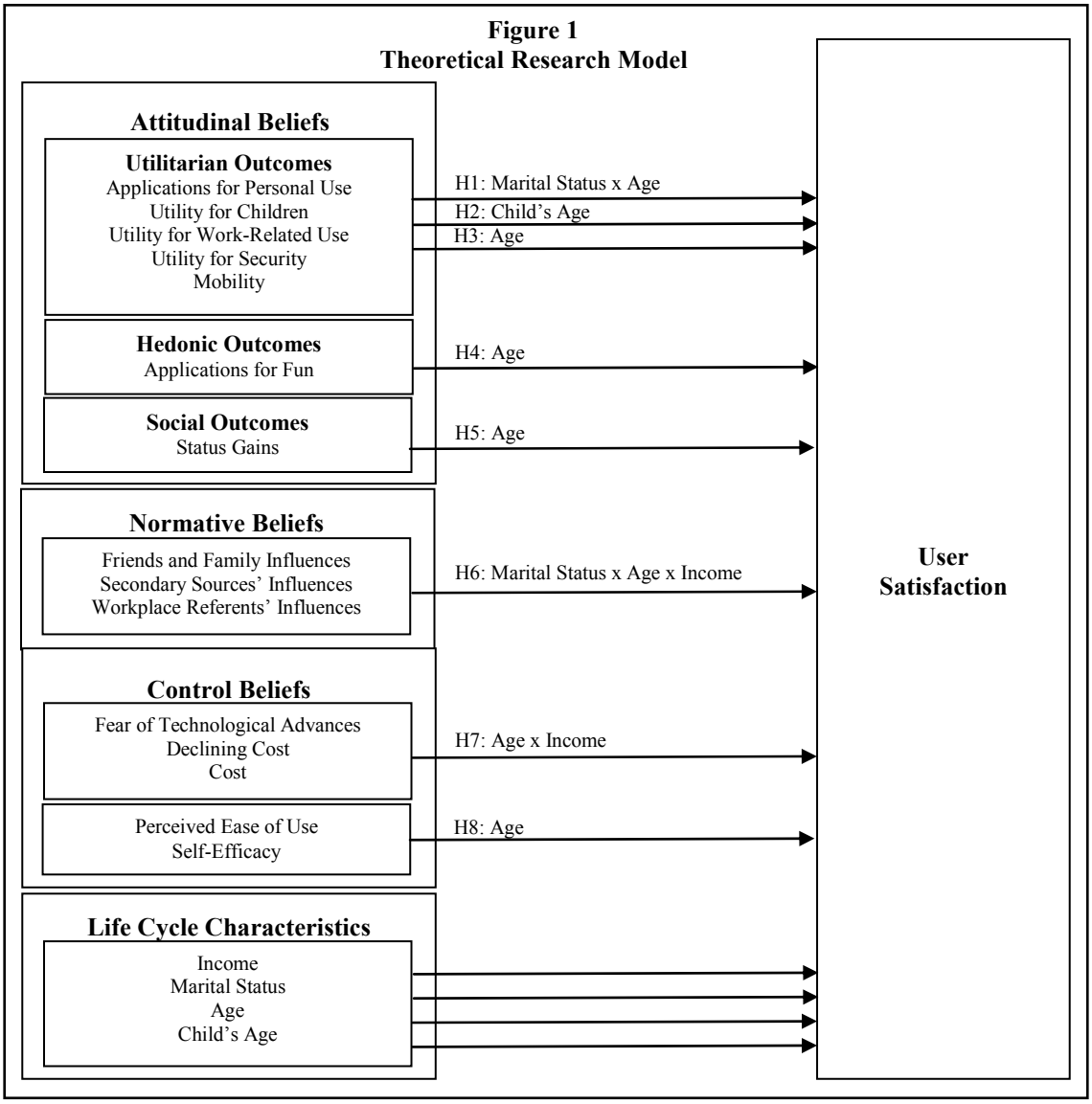


Table 2: Variables and Definitions		
Beliefs and Characteristics	***Variables***	***Definitions***
Attitudinal Beliefs	Applications for Personal Use	The extent to which using a mobile phone enhances the effectiveness of household activities (adapted from Venkatesh & Brown, 2001).
	Utility for Children	The extent to which using a mobile phone enhances the children's effectiveness in their activities (adapted from Venkatesh & Brown, 2001).
	Utility for Work-Related Use	The extent to which using a mobile phone enhances the effectiveness of performing work-related activities (adapted from Venkatesh & Brown, 2001).
	Utility for Security	The extent to which using a mobile phone increases the security of its user and his/her family.
	Mobility	The extent to which a mobile phone allows to use only this telephone to perform all personal and professional activities.
	Applications for Fun	The pleasure derived from mobile phone use (adapted from Venkatesh & Brown, 2001). These are specific to mobile phone usage, rather than general traits (adapted from Brown & Venkatesh, 2005; see Webster & Martocchio, 1992, 1993).
	Status Gains	The increase in prestige that coincides with the purchase of a mobile phone for home use (adapted from Venkatesh & Brown, 2001).
Normative Beliefs	Friends and Family Influences	"The extent to which the members of a social network influence one another's behaviour" (Venkatesh & Brown, 2001, p. 82). In this case, the members are friends and family (Brown & Venkatesh, 2005).
	Secondary Sources' Influences	The extent to which information from TV, newspaper, and other secondary sources influences behaviour (Venkatesh & Brown, 2001).
	Workplace Referents' Influences	The extent to which coworkers influence behaviour (Brown & Venkatesh, 2005; see Taylor & Todd, 1995).
Control Beliefs	Fear of Technological Advances	The extent to which rapidly changing technology is associated with fear of obsolescence or apprehension regarding a mobile phone purchase (adapted from Venkatesh & Brown, 2001).
	Declining Cost	The extent to which the cost of a mobile phone is decreasing in such a way that it inhibits adoption (adapted from Venkatesh & Brown, 2001).
	Cost	The extent to which the current cost of a mobile phone is too high (adapted from Venkatesh & Brown, 2001).
	Perceived Ease of Use	The degree to which using the mobile phone is free from effort (Davis, 1989; also adapted from Venkatesh & Brown, 2001).
	Self-Efficacy (or Requisite Knowledge)	The individual's belief that he/she has the knowledge necessary to use a mobile phone. This is closely tied to computer self-efficacy (Compeau & Higgins, 1995a, 1995b; see also Venkatesh & Brown, 2001).
Life Cycle Characteristics	Income	The individual's year gross income (see Wagner & Hanna, 1983).
	Marital Status	The individual's family status (married, single, divorced, widowed, etc.) (see Danko & Schaninger, 1990).
	Age	The individual's age (see Danko & Schaninger, 1990). In this case, age is calculated from the individual's birth date.
	Child's Age	The age of the individual's youngest child (see Danko & Schaninger, 1990). In this case, age is represented by a numeral.

Figure 1 shows that Brown and Venkatesh (2005) integrated MATH and Household Life Cycle in the following way. MATH presents five attitudinal beliefs grouped into three sets of outcomes: *utilitarian*, *hedonic*, and *social*. Utilitarian beliefs are most consistent with those found in the workplace and can be divided into beliefs related to *personal use*, *children*, and *work* (we added beliefs related to *security* and *mobility*). The extension of MATH suggested and tested by Brown and Venkatesh (2005) presents three normative beliefs: *influence of friends and family*, *secondary sources*, and *workplace referents*. As for control beliefs, they are represented in MATH by five factors: *fear of technological advances*, *declining cost*, *cost*, *perceived ease of use*, and *self-efficacy*. And, according to Brown and Venkatesh (2005), integrating MATH with a life cycle view, including *income*, *age*, *child's age*, and *marital status*, allows to provide a richer explanation of household personal computer adoption (household mobile phone usage in this study) than those provided by MATH alone. Finally, as shown in Figure 1, the dependant variable of the theoretical research model developed is related to *user satisfaction* (satisfaction in the use of mobile phone by people in household). All of the variables integrated in the theoretical research model depicted in Figure 1 are defined in Table 2.

We can see in Table 2 that the definitions of MATH variables integrated in the theoretical research model proposed in Figure 1 are, in the whole, adapted from the theoretical foundations developed by Venkatesh and Brown (2001) to investigate the factors driving personal computer adoption in American homes. As for the definitions of the variables related to the household life cycle, they were taken from Danko and Schaninger (1990) as well as Wagner and Hanna (1983), respectively. And the definitions of the two new independent variables that we added to the model are from our own. In fact, we defined these variables in accordance with which we wanted to measure regarding security and mobility before to develop and validate items measuring them on the basis of the definitions formulated.

In the reminder of the section, we develop eight research hypotheses (H1-H8) related to the model suggested in Figure 1.

H1: Marital status and age will moderate the relationship between applications for personal use and satisfaction of using a mobile phone at home.

H2: Child's age will moderate the relationship between utility for children and satisfaction of using a mobile phone at home.

H3: Age will moderate the relationship between utility for work-related use and satisfaction of using a mobile phone at home.

H4: Age will moderate the relationship between applications for fun and satisfaction of using a mobile phone at home.

H5: Age will moderate the relationship between status gains and satisfaction of using a mobile phone at home.

H6: Age, marital status, and income will moderate the relationship between the normative beliefs ((a) friends and family influences; (b) secondary sources' influences; and (c) workplace referents' influences) and satisfaction of using a mobile phone at home.

H7: Age and income will moderate the relationship between the external control beliefs ((a) fear of technological advances; (b) declining cost; and (c) cost) and satisfaction of using a mobile phone at home.

H8: Age will moderate the relationship between the internal control beliefs ((a) perceived ease of use; and (b) self-efficacy) and satisfaction of using a mobile phone at home.

In the next section of the paper, we describe the methodology followed to conduct the study.

METHODOLOGY

The study was designed to gather information concerning mobile phone adoption decisions in Atlantic Canadian households. Indeed, the focus of the study is on individuals who own a mobile phone. We conducted a telephone survey research among individuals of a large area in Atlantic Canada. 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 Brown and Venkatesh (2005) to which we added three new scales, the first two measuring other dimensions in satisfaction in the use of mobile phone by people in household, that is, utility for security and mobility, and the last one measuring user satisfaction as such. The survey instrument was then translated in French (a large part of the population in Atlantic 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, changes were made to reword items and, in some cases, to drop items that were possibly ambiguous, 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 25 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, though these minor changes had not a great importance here given the survey was administered using the telephone. As the instrument was already validated by Brown and Venkatesh (2005) and showed to be of a great reliability, that we used the scale developed by Hobbs and Osburn (1989) and validated in their study as well as in several other studies to measure user satisfaction, and that we added only few items to measure the new variables utility for security and mobility, 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.

SAMPLE AND DATA COLLECTION

First, in this study, we chose to survey people in household over 18 years taken from a large area in Atlantic Canada who own a mobile phone. To do this, undergraduate and graduate students studying at our faculty were hired to collect data using the telephone. A telephone was then installed in an office of the faculty, and students, one at a time over a 3 to 4-hour period, were asking people over the telephone to answer our survey. And in order to get a diversified sample (e.g., students, retired people, people not working, people working at home, and people working in enterprises), data were collected from 9 a.m. to 9 p.m. Monday through Friday over a 5-week period. Using the telephone directory of the large area in Atlantic Canada chosen for the study, students were randomly selecting people and asking them over the telephone to answer our survey. The sample in the present study is therefore a randomized sample, which is largely valued in the scientific world given the high level of generalization of the results got from such a sample. Once an individual had the necessary characteristics to answer the survey and was accepting to answer it, the student was there to guide him/her 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. Finally, to further increase the response rate of the study, each respondent completing the survey had the possibility to win one of the 30 Tim Hortons $10 gift certificates which were drawn at the end of the data collection. To this end, the phone number of each respondent was put in a box for the drawing. Following this data collection process, 327 people in household answered our survey over a 5-week period.

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 & Tibshirani, 1993)) with an iteration of 100 sub-sample extracted from the initial sample (327 Atlantic Canadian people). Some analyses were also performed using the Statistical Package for the Social Sciences software (SPSS 13.5). 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 analysis to test the research hypotheses.

PARTICIPANTS

The participants in this study were either relatively aged or relatively young, with a mean of 39.8 years and a large standard deviation of 14.5 years. These statistics on the age of the participants are, in fact, consistent with the growing old population phenomenon. Near from two third of the participants were female (62%). Near from 80% of the participants were married (50.9%) or single (28.4%). The gross yearly income of the respondents in the study was in the range of $0 to $50,000. Indeed, 72.4% of the respondents were winning between $0 and $50,000, and, from this percentage, 35.5% were winning between $30,000 and $50,000. And 5.5% of the respondents were winning $100,000 or over. Concerning the level of education, 25.5% of the participants in the study got a high-school diploma, 26.4% got a college degree, and 39.6% completed a baccalaureate. Only 2.1% of the participants got a doctorate, which is relatively consistent with the whole population in general. Finally, the respondents in our study were mainly full-time employees (52.5%), retired people (12%), students (11.7%), self employed (9%), part-time employees (7.4%), and unemployed (4.6%). These statistics on the respondents' occupation help to explain the large standard deviation on their age reported above. Indeed, 11.7% of the respondents were young students, while 12% were retired people. So the difference in age between these two groups is very large.

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 & 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 (327 Atlantic Canadian people). The results are presented in Table 3.

As shown in Table 3, 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 3 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 0.82 to 0.98.

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 research model, we developed a PLS model similar to those of Fillion (2005), Limayem and DeSanctis (2000), Limayem et al. (2002), 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 (327 Atlantic Canadian people). The PLS model is depicted in Figure 2.

As shown in Figure 2, all the variables of our theoretical research model, used as independent variables, are explaining 34.7% of the variance around the dependant variable user satisfaction. And half of these variables are significant, that is, they are determining factors in satisfaction of using a mobile phone by people in household. More specifically, the two more significant variables are perceived ease of use ($t = 5.18$, beta = 0.36, $p < 0.001$) and utility for security ($t = 4.38$, beta = 0.21, $p < 0.001$). Three other variables are a few less significant than these first two, but they are also very significant. These variables are child's age ($t = 2.32$, beta = 0.20, $p < 0.01$), utility for work-related use ($t = 2.26$, beta = -0.12, $p < 0.01$), as well as declining cost ($t = 2.14$, beta = 0.11, $p < 0.01$). And four other variables are significant at the level of significance requested in this study, that is, $p \leq 0.05$. These variables are marital status ($t = 1.89$,

beta = -0.11, p < 0.05), cost (t = 1.79, beta = 0.13, p < 0.05), applications for fun (t = 1.76, beta = 0.09, p < 0.05), and mobility (t = 1.70, beta = 0.08, p < 0.05).

Table 3: Means, Standard Deviations, Composite Reliability Indexes, Correlations, and Average Variance Extracted of Variables

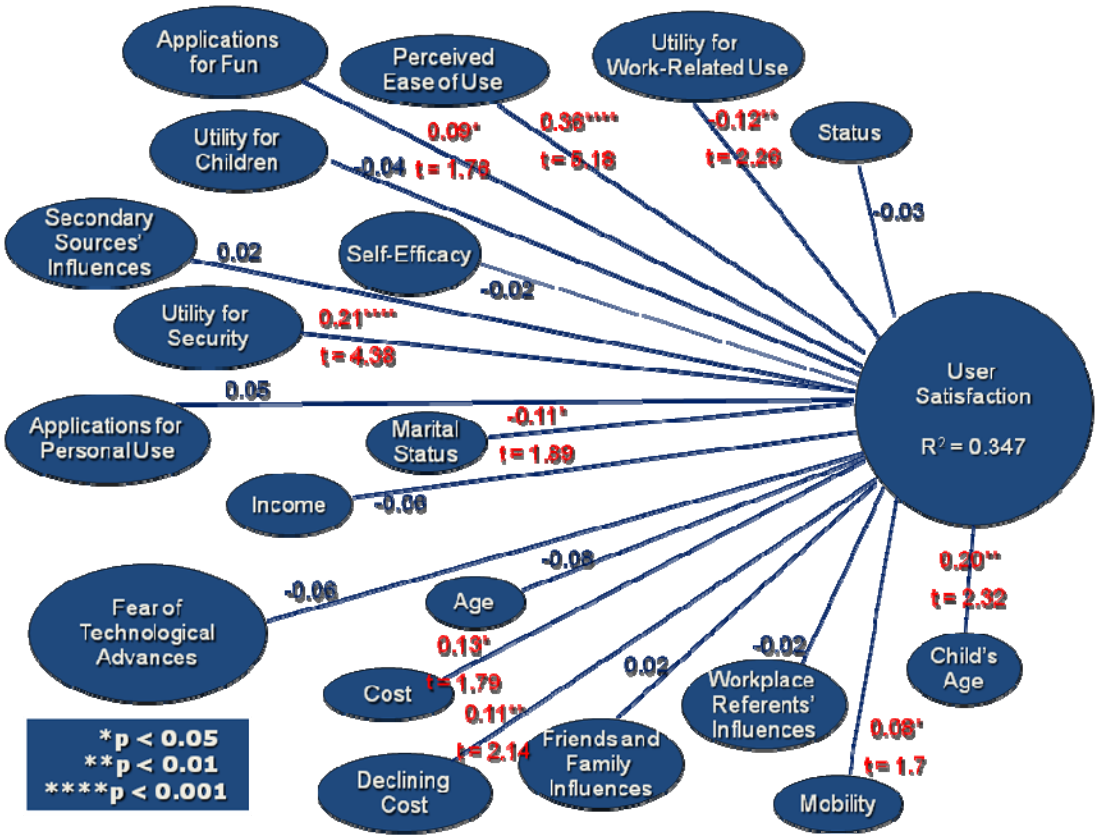
Variable	*M*	*SD*	*Relia-bility Index*	*Correlations and Average Variance Extracted*[d]																		
				1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*	*20*
1. Applications for Personal Use	3.84	1.92	**0.82**	**0.77**																			
2. Utility for Children	2.07	2.52	**0.96**	.27	**0.94**																		
3. Utility for Work-Related Use	3.17	2.46	**0.91**	.39	.10	**0.88**																	
4. Utility for Security	5.62	1.68	**0.89**	.21	.16	-.04	**0.85**																
5. Mobility	3.55	2.03	**0.88**	.30	.05	.23	.09	**0.84**															
6. Applications for Fun	2.88	1.96	**0.89**	.35	.05	.23	.13	.25	**0.82**														
7. Status Gains	2.45	1.72	**0.93**	.18	.15	.19	.13	.31	.37	**0.90**													
8. Friends and Family Influences	3.66	2.27	**0.93**	.26	.05	.16	.13	.19	.43	.40	**0.88**												
9. Secondary Sources' Influences	3.24	2.25	**0.90**	.17	.09	.08	.10	.09	.25	.23	.36	**0.87**											
10. Workplace Referents' Influences	3.12	2.41	**0.98**	.26	-.03	.37	.04	.19	.31	.29	.53	.33	**0.98**										
11. Fear of Technological Advances	3.21	1.97	**0.83**	-.06	.10	.04	.10	-.09	.04	.15	.13	.15	.16	**0.79**									
12. Declining Cost	4.14	1.88	**0.89**	.17	.13	.08	.12	.12	.06	.05	.04	.13	.08	-.04	**0.85**								
13. Cost	4.38	1.83	**0.96**	.07	.01	.04	.16	.13	.04	.22	.16	.07	.10	.24	-.09	**0.96**							
14. Perceived Ease of Use	5.69	1.45	**0.88**	.19	-.05	.09	.15	.27	.24	.18	.17	-.02	.20	-.11	.15	.00	**0.80**						
15. Self-Efficacy	6.39	1.02	**0.93**	.18	-.14	.04	.12	.18	.12	.03	.11	-.08	.12	-.12	.15	-.00	.66	**0.91**					
16. Income[a]	NA	NA	**NA**	.04	.11	.09	-.12	-.11	-.32	-.23	-.24	-.05	-.04	-.07	.02	-.11	-.05	-.00	**NA**				
17. Marital Status[a]	NA	NA	**NA**	-.04	-.03	-.22	.27	-.02	.09	-.06	.06	.00	-.04	.04	-.11	.03	-.03	-.02	-.22	**NA**			
18. Age[b]	39.80	14.50	**NA**	.12	-.24	.20	.04	.21	.46	.22	.31	.16	.37	-.05	-.03	.10	.31	.18	-.41	.16	**NA**		
19. Child's Age[c]	16.29	9.09	**NA**	.11	.09	-.03	-.06	.02	.33	.12	.24	.13	-.09	-.06	-.07	.09	.16	.14	-.21	.07	-.08	**NA**	
20. User Satisfaction	5.46	1.41	**0.86**	.18	.04	-.09	.31	.20	.21	.11	.16	.06	.03	-.10	.21	-.06	.40	.27	-.13	.10	.06	.07	**0.71**

[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 continuous variable. It was measured using the respondents' birth date.
[c]This variable was coded using the age of the respondents' youngest child.
[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.

Finally, to measure interaction effect of moderator variables (the life cycle stage characteristics: income (I), marital status (MS), age (A), and child's age (CA)) in order to verify hypotheses 1 to 8, 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 into information systems (IS) journals, Carte and Russell (2003) found nine errors frequently committed by researchers while estimating such an effect, and provided solutions (see the paper for more details). So we tried to avoid these nine errors in applying their solutions to test hypotheses 1 to 8. Indeed, among others, in the verification of hypotheses 1 to 8 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, $^R^2$) is greater than 0.

Figure 2
PLS Model to Get Significant Variables and Percentage



For a matter of space, given that the test of hypotheses 1 to 8 required the development of several PLS structural equation models (two models per hypothesis, that is, 16 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 percentage of variance explained by all the variables of the theoretical research model previously (see Figure 2), for each PLS model developed, we used the PLS bootstrap resampling procedure with an iteration of 100 sub-sample extracted from the initial sample (327 Atlantic Canadian people) to ensure the stability of the model.

Concerning hypothesis 1 related to the independent variable applications for personal use (APU), the path from the latent variable APU*MS*A to the dependent variable user satisfaction is significant (t = 1.698, beta = -0.154, $p < 0.05$) and there is a change in R^2 ($^R^2 = 0.011$). Thus,

as we expected, the moderator variables marital status and age have an influence on the relationship between applications for personal use and satisfaction of using a mobile phone by people in household. Also hypothesis 1 is supported. The scenario is different for hypothesis 2 related to the independent variable utility for children (UC). The path from the latent variable UC*CA to the dependent variable user satisfaction is not significant (t = 0.188, beta = 0.034) and there is no change in R^2 ($\hat{}R^2 = 0.000$). So, contrary to our expectations, the moderator variable child's age has not an influence on the relationship between utility for children and satisfaction of using a mobile phone by people in household. As a result, hypothesis 2 is not supported. For hypothesis 3 related to the independent variable utility for work-related use (UWRU), the path from the latent variable UWRU*A to the dependent variable user satisfaction is significant (t = 1.743, beta = -0.267, $p < 0.05$) and there is a change in R^2 ($\hat{}R^2 = 0.005$). Thus, as we expected, the moderator variable age has an influence on the relationship between utility for work-related use and satisfaction of using a mobile phone by people in household. Hypothesis 3 is therefore supported. Regarding hypothesis 4 related to the independent variable applications for fun (AF), the path from the latent variable AF*A to the dependent variable user satisfaction is not significant (t = 0.450, beta = -0.068) and there is no change in R^2 ($\hat{}R^2 = 0.000$). Contrary to our expectations, the moderator variable age has not an influence on the relationship between applications for fun and satisfaction of using a mobile phone by people in household. As a result, hypothesis 4 is not supported. And the scenario is similar for hypothesis 5 related to the independent variable status gains (SG), the path from the latent variable SG*A to the dependent variable user satisfaction is not significant (t = 0.466, beta = 0.093), but there is a small change in R^2 ($\hat{}R^2 = 0.002$). So, contrary to our expectations, the moderator variable age has not an influence on the relationship between status gains and satisfaction of using a mobile phone by people in household. Consequently, hypothesis 5 is not supported.

In the case of hypothesis 6 (a) related to the independent variable friends and family influences (FFI), the path from the latent variable FFI*MS*A*I to the dependent variable user satisfaction is not significant (t = 0.477, beta = -0.068), but there is a substantial change in R^2 ($\hat{}R^2 = 0.006$). So, contrary to our expectations, the moderator variables marital status, age, and income have not an influence on the relationship between friends and family influences and satisfaction of using a mobile phone by people in household. As a result, hypothesis 6 (a) is not supported. Concerning hypothesis 6 (b) related to the independent variable secondary sources' influences (SSI), the path from the latent variable SSI*MS*A*I to the dependent variable user satisfaction is significant (t = 1.666, beta = -0.169, $p < 0.05$) and there is a change in R^2 ($\hat{}R^2 = 0.002$). Thus, as we expected, the moderator variables marital status, age, and income have an influence on the relationship between secondary sources' influences and satisfaction of using a mobile phone by people in household. And hypothesis 6 (b) is supported. The scenario is similar for hypothesis 6 (c) related to the independent variable workplace referents' influences (WRI), the path from the latent variable WRI*MS*A*I to the dependent variable user satisfaction is significant (t = 1.778, beta = -0.195, $p < 0.05$) and there is a change in R^2 ($\hat{}R^2 = 0.001$). Thus, as

we expected, the moderator variables marital status, age, and income have an influence on the relationship between workplace referents' influences and satisfaction of using a mobile phone by people in household. Consequently, hypothesis 6 (c) is supported.

Regarding hypothesis 7 (a) related to the independent variable fear of technological advances (FTA), the path from the latent variable FTA*A*I to the dependent variable user satisfaction is not significant (t = 0.493, beta = 0.092), but there is a small change in R^2 ($\hat{}R^2$ = 0.001). Thus, contrary to our expectations, the moderator variables age and income have not an influence on the relationship between fear of technological advances and satisfaction of using a mobile phone by people in household. Hypothesis 7 (a) is then not supported. The scenario is similar for hypothesis 7 (b) related to the independent variable declining cost (DC), the path from the latent variable DC*A*I to the dependent variable user satisfaction is not significant (t = 0.653, beta = -0.139), but there is a change in R^2 ($\hat{}R^2$ = 0.003). So, contrary to our expectations, the moderator variables age and income have not an influence on the relationship between declining cost and satisfaction of using a mobile phone by people in household. Consequently, hypothesis 7 (b) is not supported. And the scenario is also similar for hypothesis 7 (c) related to the independent variable cost (C), the path from the latent variable C*A*I to the dependent variable user satisfaction is not significant (t = 0.498, beta = -0.081), but there is a change in R^2 ($\hat{}R^2$ = 0.004). Thus, contrary to our expectations, the moderator variables age and income have not an influence on the relationship between cost and satisfaction of using a mobile phone by people in household. As a result, hypothesis 7 (c) is not supported.

Finally, concerning hypothesis 8 (a) related to the independent variable perceived ease of use (PEU), the path from the latent variable PEU*A to the dependent variable user satisfaction is not significant (t = 0.816, beta = -0.334), but there is a substantial change in R^2 ($\hat{}R^2$ = 0.005). Thus, contrary to our expectations, the moderator variable age has not an influence on the relationship between perceived ease of use and satisfaction of using a mobile phone by people in household. As a result, hypothesis 8 (a) is not supported. The scenario is different regarding hypothesis 8 (b) related to the independent variable self-efficacy (SE), the path from the latent variable SE*A to the dependent variable user satisfaction is significant (t = 1.726, beta = -0.512, $p < 0.05$) and there is a substantial change in R^2 ($\hat{}R^2$ = 0.006). So, as we expected, the moderator variable age has an influence on the relationship between self-efficacy and satisfaction of using a mobile phone by people in household. Consequently, hypothesis 8 (b) is supported.

In the next and last section of the paper, we discuss about some implications of the more important findings of the study.

DISCUSSION AND CONCLUSIONS

This last section is devoted to a discussion about the results of the study and some conclusions. And, to support our discussion and conclusions, we provide the reader with a more

detailed view of the PLS structural equation model developed to get the significant variables in the study, including the percentages of variance explained of variables (see Table 4).

As shown in Table 4 (and Figure 2), the nineteen independent variables examined in the study explained 34.7 percent ($R^2 = 0.347$) of the variance in satisfaction in the use of mobile phone by people in household. And we can also see in Table 4 that the nine variables who showed to be significant (see also the significant beta path coefficients in Figure 2), that is, utility for work-related use, utility for security, mobility, applications for fun, declining cost, cost, perceived ease of use, marital status and child's age, explained alone 24.6 percent of the variance in satisfaction of using a mobile phone by people in household. Thus, these nine variables are assuredly very important factors to take into account in future studies on the mobile phone and on the part of mobile phone providers, and more particularly perceived ease of use and utility for security which explained alone 18.7 percent of this variance (see Table 4). It is very interesting to see here that the two new variables that we added to the Brown and Venkatesh's (2005) research model, that is utility for security and mobility, showed to be very significant ($p < 0.001$ and $p < 0.05$, respectively; see Table 4) in satisfaction of using a mobile phone by people in household. Indeed, the present study showed that people are, to some extent, using a mobile phone for a matter of security (the mobile phone is useful for their own security and those of their families) and mobility (the mobile phone provides them with the possibility to use only this telephone to perform all their personal and professional activities). So here are two new variables which we can add to the integrated research model of MATH and household life cycle characteristics suggested by Brown and Venkatesh (2005) to test in future studies. In addition, these two new variables may be included in the sales marketing plan of mobile phone providers.

In the large-scale study in which Brown and Venkatesh (2005) integrated MATH and some household life cycle characteristics (as moderating variables), the integrated model explained 74 percent of the variance in intention to adopt a personal computer for home use, a substantial increase of 24 percent over baseline MATH that explained 50 percent of the variance. In the present study, we used the integrated model proposed by Brown and Venkatesh (2005). We also added two new independent variables to the model, that is, utility for security and mobility. And we used the household life cycle variables as moderating variables in the research model as did Brown and Venkatesh (2005). Finally, given that we investigated the perceptions of people already using a mobile phone instead of those having the intention to adopt a mobile phone, as did Brown and Venkatesh (2005) for the personal computer, we used the dependent variable user satisfaction instead of behavioural intention. And the model explained 34.7 percent of the variance in satisfaction of using a mobile phone by people in household (see Table 4 and Figure 2). Thus, in this study, our theoretical research model explained a smaller percentage of variance than those explained by MATH alone (without the household life cycle characteristics and using behavioural intention as dependent variable).

Table 4: Beta Path Coefficients, T-Values, and Percentages of Variance Explained of Variables			
Variable	***Beta***	***t***	***R^2***
Applications for Personal Use	0.054	0.925	0.002
Utility for Children	-0.039	0.726	0.001
Utility for Work-Related Use	-0.119**	2.263	0.008
Utility for Security	0.210****	4.379	0.104
Mobility	0.079*	1.704	0.004
Applications for Fun	0.089*	1.764	0.004
Status Gains	-0.029	0.511	0.000
Friends and Family Influences	0.022	0.357	0.000
Secondary Sources' Influences	0.015	0.248	0.001
Workplace Referents' Influences	-0.020	0.314	0.000
Fear of Technological Advances	-0.059	0.551	0.005
Declining Cost	0.111**	2.137	0.011
Cost	0.125*	1.794	0.021
Perceived Ease of Use	0.355****	5.180	0.083
Self-Efficacy	-0.019	0.271	0.069
Income	-0.059	0.687	0.001
Marital Status	-0.111*	1.892	0.000
Age	-0.076	0.640	0.014
Child's Age	0.201**	2.323	0.011
*p < 0.05; **p < 0.01; ****p < 0.001.			

Further, in a previous study in which we investigated the intention to buy a mobile phone by people in household (see Fillion & Berthelot, 2007), we also used the theoretical research model suggested by Brown and Venkatesh (2005) to which we added the same two independent variables utility for security and mobility than we included in the present study in which we investigated satisfaction in the use of mobile phone by people in household. And our model explained 50 percent of the variance in intention to buy a mobile phone, while in the present study our model explained 34.7 percent of the variance in satisfaction of using a mobile phone. Of course, the dependent variable was different in the two studies. Indeed, we used behavioural intention in the previous study and user satisfaction in the present study. Hence we can see that the variable behavioural intention is probably more appropriate as dependent variable in the research model proposed by Brown and Venkatesh (2005) than is user satisfaction, even when the model is augmented of some new independent variables. Further, with the addition of the life cycle stage variables income, marital status, age and child's age as moderating variables to the

model, as did Brown and Venkatesh (2005), to test our research hypotheses, we have just observed a 3.1 percent increase in variance explained, that is, 37.8 percent. However, it is to be noted that, in the model we used in this study, more independent variables showed to be good predictors in satisfaction of using a mobile phone by people in household than did independent variables in the model we used in the previous study in intention to adopt a mobile phone for household use. So, although the result of our test seems, at first, not to be very conclusive, in this study, we found several interesting things to advance knowledge in this new and exciting field of adoption and use of technology in households.

First, we found nine very important variables that seem to be good predictors in satisfaction of using a mobile phone by people in household, and more particularly perceived ease of use, utility for work-related use, declining cost as well as the two new variables that we added to the Brown and Venkatesh's (2005) model, utility for security and mobility (see Table 4). These nine variables are also very important to take into account by mobile phone providers to design new mobile phones still better adapted to people's needs and to perform their sales marketing. Second, we found that people are, to some extent, using a mobile phone for a matter of security and mobility, given our two new variables utility for security and mobility showed to be very significant (see Table 4). Third, we found that it is probably much more appropriate to use the dependent variable behavioural intention instead of user satisfaction in the model proposed by Brown and Venkatesh (2005), even augmented of our two new independent variables utility for security and mobility, given the percentage of variance explained in intention to adopt a mobile phone for household use in our previous study is relatively higher. But, according to us, it is also appropriate to include user satisfaction as dependent variable in the model given we found more good predictors in satisfaction in the use of mobile phone in the present study than in the previous one in which we used behavioural intention as dependent variable. The dependent variable *use behaviour* proposed by Thompson et al. (1991) may also be tested in future studies. Also, we suggest the test of new independent variables which may explain a greater percentage of variance in satisfaction of using a mobile phone by people in household in future studies. To this end, we recommend three new independent variables in the next paragraph. Finally, the results of this study provided the evidence that it is far better to use the household life cycle variables as moderating variables in the model, as did Brown and Venkatesh (2005), given the percentage of variance explained in intention to adopt a new technology in household by the model tested by these authors was significantly higher. Indeed, we used the household life cycle variables as moderating variables in the theoretical research model of this study instead of independent variables, as we have made in the previous study, and the percentage of variance explained by the model in satisfaction of using a mobile phone by people in household has been higher.

It would be interesting in future studies to add some other new variables to the actual theoretical research model (those suggested by Brown and Venkatesh (2005) augmented with the two new variables that we tested in the present study, depending on the technology examined

naturally) in order to try to explain still more variance in satisfaction of using a new technology in household. For example, the variable *attention* might be added in social outcomes (a lot of people, particularly young and old people, are feeling to be alone in the actual stressing world, in which both men and women are working and get very busy, so the mobile phone might be a good way to communicate with other people every time and everywhere to get the feeling to be less alone), the variable *social norm* might also be added in social outcomes (who knows, people might be using a mobile phone just to do as everybody!), and the variable *control* might be added in utilitarian outcomes (some people might be using a mobile phone to control other people in their family or others; maybe another kind of Big Brother!). It would be also interesting to test the actual model in other situations and with other populations. For example, in a subsequent study, we tested the actual model with Atlantic Canadian people who are using high speed Internet at home. As in this study, we used the dependent variable user satisfaction given the respondents were already using high speed Internet. The results of the study will follow in a subsequent paper. It will be interesting to see whether the results remain the same as those got from people who are using a mobile phone at home.

Regarding the limitations of this study, as pointed out by Brown and Venkatesh (2005), the primary limitation is the reliance on a single informant. It is possible that other members of the household would have provided different responses concerning the motivations to use a mobile phone at home. Future research in household use of technology should incorporate responses from multiple members of the household to truly assess the nature of household use. A second limitation of the study is that it was conducted in only one area in Atlantic Canada. If the study would have been carried out in the whole Atlantic Canada, its results would be of a higher level of generalization. But the fact that the sample of the study was a randomized sample allows a high level of generalization of its results. Another limitation of the study is the administration of the survey instrument over the telephone. Some respondents might have not very well understood some items of the survey instrument over the telephone and then provided more or less precise ratings on these items, introducing the possibility of some response bias. But the method we privileged in this study to administer the survey instrument is not an exception to the rule: each method has its own limitations!

To conclude, much more research will be needed on the use of technology in households in order to better understand its impacts on people's daily life. The research will allow, among others, at least to minimize, if not to remove, some negative impacts of technology in people's daily life in the future and to develop new technologies still better adapted to people's needs. We will continue to inquire into this new and exciting field.

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PREDICTING LEADERSHIP SUCCESS IN AGILE ENVIRONMENTS: AN INQUIRING SYSTEMS APPROACH

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ABSTRACT

In recent years a host of new agile software development methodologies have been introduced. These methodologies emphasize people over process, software over documentation, customer collaboration over contract negotiation and responding to change over following a plan. While there is still much debate over the effectiveness of these new agile methods, there is general agreement that they are quite different from the traditional process oriented approaches. One major implication of these differences is the need for a less rigid and formal approach to project management. Because of Agile's focus on people and collaboration combined with the need to embrace change, leadership requirements are vastly different than those using traditional process oriented approaches to software development. Personality characteristics of successful agile managers may contrast sharply with those of more traditional project managers. In this environment a leader's personality profile and way of interacting with others is at least as important as their intellectual ability and "hard" project management skills. In current management literature, the Myers Briggs Type Indicator (MBTI) has been cited extensively as an aid in leadership development and identification of individuals most likely to be successful leaders (Fitzgerald & Kirby, 1997; Gardner & Martinko, 1996). This paper will discuss the MBTI approach as it has been applied in the literature. As we will see, while a good tool for assessing dimensions related to an individual's view and perceptions of the world, there is also a need for an evaluative approach that emphasizes an individual's mode of interacting in a team environment. In this paper, such an approach is proposed, an inquiring systems perspective, based on Churchman's five modes of inquiry. The MBTI will be compared to this inquiring systems approach within the context of agile leadership requirements. This analysis suggests that the inquiring systems perspective provides a more effective tool for assessing an individual's propensity for success in an agile software development environment.

INTRODUCTION

Throughout the last 40 years software development projects have continued to be over budget, overdue and lacking in both level of quality and desired functionality (McDonald, 2001). Various potential reasons have been cited for this lack of success, but there is one point of agreement. Something definitely appears to be "broken" in the software development process

indicating that there may be a better way to engineer software. Some believe the answer lies in the host of new "agile methodologies" that have arrived on the scene in recent years. These methodologies emphasize people over process, software over documentation, customer collaboration over contract negotiation and responding to change over following a plan. While there is still much debate over the effectiveness of these new agile methods, there is general agreement that they are quite different from the traditional process oriented approaches. For example, in an agile environment, the overall project is not planned up front, but in small iterations and developers are "self-organizing" in that the teams determine the best way to handle the work. (Boehm & Turner, 2004). One major implication of these differences is the need for a less rigid and formal approach to project management. A very rigid and controlling type of manager, with a successful track record managing process driven software projects, may not be the right candidate to manage an agile project.

Many studies have attempted to map personality styles/cognitive styles to analysts and programmers. Very few, if any, have examined characteristics of leaders in software development teams. The agile phenomenon (with its emphasis on self organizing teams, interchangeable roles, managers as facilitator/orchestrator rather than as controller) makes such an endeavor all the more important.

What leadership styles do we have? They may not be adequate to understand what is required of "agile" leaders. Literature on leadership can be categorized into one of three broad categories or typologies of leadership: Transactional, Transformational and Ecovision. As suggested by the name, transactional leaders approach their followers with a bartering mentality (i.e. exchanges rewards and promises for effort (Doyle and Smith, 1999)). A transactional leader will focus on what followers want to get from their work and attempt to ensure they get it if performance is good (Doyle and Smith, 1999). This type of leader responds to the self-interests of subordinates. In direct contrast to a transactional leader, transformational leadership involves getting followers to "transcend their own self-interest for the sake of the team, organization or larger polity" (Doyle and Smith, 1999). This type of leader attempts to "raise employee's awareness or level of consciousness about the significance and value of designated outcomes and ways of reaching them " (Doyle and Smith, 1999). Transformational leaders try to change followers' needs by broadening their range of wants and needs; in this way they are seen as "change agents". Although transactional leaders and transformational leaders differ in their ways of motivating followers, both rely on their authority or formal positions of power. In this way, both of these leadership styles tend to be more autocratic and better suited to traditional organizations. The third category of leadership is referred to as ecovision. Ecovision is characterized as "leadership through self-identity" (Shareef, 1991). According to Shareef, 1991, ecovision theory sees leaders combining two distinct components: the ecological perspective with emphasis on a holistic relationship between the organization and the environment and the ability to produce and renew realistic identities that enhance the environmental context in which the organization functions. Leaders with "ecovision" are visionaries who "design an ecological

fit between the organization and the environment". Ecovision has been characterized as assertive in that an organization uses the environment as a basis to be assertive with a realistic self-image and a continually updated identity (Shareef, 1991).

In their book *Management Systems: A Global Perspective,* Cavaleri and Obloj discuss a continuum of leadership types with one extreme being work-oriented and autocratic while the other extreme is people-oriented and democratic. Traditional leadership styles characterized by controlling leaders will fall closer to the work-oriented, autocratic extreme, while agile leaders will tend to be closer to the people-oriented democratic extreme.

As illustrated, there are different leadership styles, some of which are compatible with traditional organizational structures, while others are more suitable for organizational cultures that are conducive to adaptation and innovation. Agile development is more consistent with the latter. Some experts in the area of agile methodologies hold the opinion that agile leadership characteristics cannot necessarily be taught, but may be more dependent upon the predisposition of the individual (Highsmith, 2004). Within the leadership literature, the Myers Briggs Type Indicator (MBTI) has been cited extensively as an aid in leadership development and identification of individuals most likely to be successful leaders (Fitzgerald & Kirby, 1997; Gardner & Martinko, 1996). While the MBTI is a good tool for assessing dimensions related to an individual's view and perceptions of the world, there is also a need for an evaluative approach emphasizing an individual's mode of interacting in a team environment. This paper proposes such an approach, based on Churchman's five modes of inquiry.

We adopt an inquiring systems perspective to identify traits that will enhance the scope and effectiveness of leaders in an agile environment. Churchman's design of inquiring systems is the conceptual basis for this analysis. The use of this intellectual framework for assessing the characteristics of managers is not new (Vandenbosch, 2001). However, it has not been used in the context of leadership in an agile software development environment.

In his 1971 book, *The Design of Inquiring Systems*, West Churchman proposed five modes of inquiry for "understanding how we go about gathering information, asking questions, solving problems and making decisions" (Kienholz, 1999). Justus Buchler, a philosopher at Columbia University, independently identified five distinct philosophical methodologies very similar to Churchman's. Buchler's five methodologies or "styles" have a direct correlation to Churchman's five modes of inquiry (Harrison and Bramson, 1982). These were further refined and developed into "styles of thinking" by Harrison and Bramson, 1982. This paper describes leadership characteristics that are conducive to agile software development environments and maps these characteristics to the five modes of inquiry identified by Churchman. In characterizing each mode, reference is also made to Harrison and Bramson's styles of thinking. With agile's focus on people over processes, it is critical to a project's success to have the right types of people "leading the charge". Mapping desirable characteristics of agile leaders to specific inquiry modes will provide insight into the types of managers that are most likely to be successful in an environment using agile development methodologies. The goal of this paper is

to introduce a viable approach to assessing an individual's propensity for leadership success in an agile software development environment.

The first part of this paper compares traditional process driven approaches to agile approaches, highlighting their philosophical and methodological differences. Next is a discussion of the roles and responsibilities of agile leaders as specified in the agile management literature. This is followed by an explanation of the MBTI and a discussion of its application within the context of management research on leadership. Then, an explanation and description of Churchman's five modes of inquiry is presented. Next, characteristics of agile leaders are categorized into dimensions followed by a mapping of these dimensions to Churchman's five modes of inquiry. These same dimensions are then discussed as they relate to the MBTI. Finally, a summary with conclusions is presented followed by suggestions for further research.

TRADITIONAL VERSUS AGILE

PHILOSOPHICAL DIFFERENCES

In order to understand the rationale behind traditional and agile methods, it is necessary to discuss the basic philosophical differences between the two. Traditional and agile perspectives are fundamentally different in their view of the software development process and software systems in general.

Traditional process oriented approaches to software engineering strive to incorporate processes in order to control factors that affect stability. "Software process traditionalists view changes as defects and regard the dreaded "scope creep" as one of the demons of development" (Highsmith, 2002) "Much software engineering research/practice seemed to be trying to prevent complexity, change, and the uncertainties from getting out of control" (Charette, 2003). It reflects the mindset that with enough planning, all issues can be resolved and an optimal solution can be obtained. Heavily influenced by engineering and scientific methods of inquiry, traditional approaches value processes and technology over people and their competencies (Brown, etal, 2004). This perspective aligns with what has been described as "obsolete" traditional ISD goals that include:

1) proper IS analysis and design requires formal, often lengthy, analysis and design activities in order to minimize maintenance activities,

2) one must achieve user satisfaction (versus the idea that user's needs are always changing and can never be considered "satisfied")

3) one can and must create a reasonably complete and traceable set of abstract requirements

4) complete specifications can and should be derived from these abstract requirements, and

5) ISD requires rigorous advance planning (Truex, et al 1999).

These objectives support a stable rather than emergent organization.

In direct opposition to the traditional view, agile approaches encourage developers to "embrace change". "Agilists welcome change as an opportunity to help the customer respond to marketplace turbulence" (Highsmith, 2002). In his book *Agile Software Development Ecosystems*, Highsmith emphasizes the similarities between ecosystems ("organisms and their environment") and the software development environment. This perspective views software systems as being very similar to living things that must adapt to constantly changing surroundings and situations. In such a scenario, planning too far ahead can be counterproductive because constant change will cause long term plans to become obsolete. Rigorous processes and inflexible plans discourage change. While traditional approaches value these processes and technology over people, Agile's emphasis is on individuals and interactions. (Highsmith, 2002). Agilists believe that customers, developers and organizational culture have a significant influence on the success of a project (Boehm, 2004). These underlying concepts of the agile approach align well with what have been identified as new ISD goals for supporting emergent organizations; they include:

1) always analysis,
2) dynamic requirements negotiations,
3) incomplete and usefully ambiguous specifications,
4) continuous redevelopment and
5) having an adapatability orientation (Truex, etal, 1999).

METHODOLOGICAL DIFFERENCES

This section highlights the basic differences between traditional process oriented methodologies and agile methodologies. It includes a discussion of how these differences influence the project manager's role and responsibilities.

"Plan-driven methods are characterized by a systematic engineering approach to software that carefully adheres to specific processes in moving software through a series of representations from requirements to finished code" (Boehm, 2004). In plan-driven methods, comprehensive documentation is required during each phase of the project. Plan-driven methods

can be implemented using a waterfall approach where a given phase must be completed prior to beginning the next phase or using an incremental approach where the entire system is designed, but coded and tested incrementally. In either case, comprehensive documentation and traceability requirements must be met. The processes are highly standardized with the idea being to have repeatable processes in place that can be continuously improved. Typically, developers are skilled in a particular area and assigned tasks within their area of specialization. The project manager plans, estimates, schedules and assigns tasks at the beginning of the project. Any changes to this plan must follow a well-defined change control process. Thereafter, the manager is in charge of project monitoring and control in addition to acting as liaison to the client and upper management (Conger, 1994). Agile methods differ in terms of team structure as well as development process. "A truly agile method must include all of the following attributes: iterative (several cycles), incremental (not deliver the entire product at once), self-organizing (teams determine the best way to handle work), and emergence (processes, principles, work structures are recognized during the project rather than predetermined)" (Boehm, 2004). While traditional methods prescribe planning and designing the entire product up front, agile methods call for designing, coding, testing and delivering the product in multiple relatively small iterations. These iterations contain features agreed upon between the customers and developers. Agile teams determine the best way to handle the work among themselves, while in a traditional development environment, the project manager assigns roles and responsibilities. And, while traditional development projects have well-defined processes, standards and pre-planned work structures, the processes, principles and work structures are evolved during the course of an agile project. Furthermore, these processes, principles and work structures will most likely vary from project to project in an agile environment.

Within the development environment, the philosophy and methodology employed play a major part in defining the project manager's roles and responsibilities. For example, as stated above, a project manager on a process driven project would plan the project up front, estimating, scheduling and assigning tasks. However, since agile teams are self-organizing, this major responsibility in a traditional project would not be part of the manager's role in an agile project. One major philosophical difference between agilists and traditionalists involves optimization versus exploration. As stated above, traditionalists assume that with enough planning, an optimal solution can be obtained, whereas agilists take the position that exploration to find new ways of solving problems fosters innovation (Highsmith, 2002). Optimization is a change resistant process (Highsmith, 2002), whereas exploration encourages change. "Exploration is difficult; it causes anxiety, trepidation, and sometimes even a little fear. Agile project managers need to encourage and inspire team members to work through the difficulties of a high-change environment". (Highsmith, 2004) These are just a couple of examples illustrating how the role of an agile project manager differs from that of a traditional project manager. The next section refers to the agile methodology literature to further explore the project manager's role in an agile environment in order to identify desirable characteristics of an agile project manager.

THE ROLE OF THE AGILE PROJECT MANAGER

In reviewing the literature on agile management, a consistent theme emerges. That is the idea that managers of agile projects act more as leaders, facilitators and coaches rather than authoritarians who make every decision and strive to control changes. Highsmith (2001, 2002, 2004) refers to the leadership-collaboration management model where leadership replaces command and collaboration replaces control. According to this model, responsibilities include setting direction, providing guidance, facilitating the decision-making process and expediting connections between people and teams. He states that "collaborative managers revel in connectivity and real world ambiguity, believing in people and passion" (Highsmith, 2001). These types of leaders encourage change and inspire exploration. They are able to create a vision and motivate people to work on something "outside the norm" (Highsmith, 2004). The focus is not inward meaning they do not look only to a plan consisting of schedule, scope and resource estimates. Agile managers take an outward-facing perspective in that they constantly peruse the external environment looking for factors that may affect the project. As these are identified, they guide the project, making the right course changes to keep it flowing smoothly. (Chin, 2004) Guidance is provided by relying on their ability to influence the team rather than on formal authority or power. True leaders inspire team members to willingly follow rather than using coercive tactics. As facilitators, agile managers work "behind the scenes" ensuring the right things happen when they need to happen. They "cause things to be done, coordinate and report results, cause meetings to happen, coordinate their existence, keep the team on process, make notes and offer help" (Jeffries, 2001). It is inevitable that projects will face obstacles or problems that may slow progress. When this occurs, it is the manager's job to handle them. This may involve anything from "running interference" when upper management questions the process or expediting the purchase of needed technical equipment. An agile project manager's role has been defined as "a support function that provides the backbone for efficient software development" (Abrahamsson, 2003). As leaders, they "set goals and constraints and provide boundaries within which innovation can flourish" (Cockburn, 2001). They do not directly make all decisions, but provide an environment that facilitates group decision-making. Agile managers understand that "who makes the decisions isn't as important as collaboration on information to make informed decisions" (Cockburn, 2001). It is their job to get team members to make good decisions (Beck, 2000). They need the ability to trust their team members in exercising their skills effectively. At the same time, agile managers need to know when something is not working well and the team is unable to solve the problem. When this occurs, they must intervene and do what is necessary to handle the issue. Therefore, managers still need to track the project, but without lots of overhead (Beck, 2000). They provide continual guidance throughout the project as opposed to presenting a policy manual at the beginning of the project. The agile manager's attitude toward the team is one of "I am helping my team do the best job

possible" rather than "I am trying to make my team do a good job" (Beck, 2000). Helping the team involves coaching and mentoring by "continuously learning, leading by example and striving to learn about their customers' needs, team or personality conflicts, new technologies and the latest wisdom on best practices in agile methods" (Krievsky, 2002). Great coaches have the ability to bring out the best in their team by motivating them to give it their all.

As evidenced by the literature, it is a commonly held belief that agile managers must be good leaders, facilitators and coaches. "Leaders are not leaders because of what they do, but because of who they are" (Highsmith, 2004). This implies that the traits required to be successful in an agile environment cannot necessarily be taught, but may depend on the predisposition and makeup of the individual. In terms of assessing individual personality profiles, the Myers Briggs Type Indicator (MBTI) has been cited extensively as it applies to leadership development and performance (Fitzgerald & Kirby, 1997; Gardner & Martinko, 1996). The next section provides an explanation of the MBTI and discusses its use in management research.

MBTI'S PERSONALITY PROFILES

The MBTI is based on Swiss psychiatrist, Carl Jung's theory of psychological type. He believed that human beings are born with certain mental and emotional possibilities. Jung identified what he saw as the two primary abilities (Fitzgerald & Kirby, 1997):

1) *the ability to gather, store, and retrieve information by observing the world around them as well as their own memories and inner states;*

2) *the ability to reflect upon that information and organize it coherently to understand and make decisions.*

Jung's typology is based on "preferences" and "opposites". Jung referred to "preferences" as "inborn, natural ways of using particular mental tools that shape a person's perspective and development" (Fitzgerald & Kirby, 1997). The Jung typology characterizes human personality in terms of three areas: perception, judgment and orientation. For each of these areas he defines two opposite preferences. The MBTI personality inventory was developed by Myers and Briggs and operationalizes Jung's theory. It is a measurement instrument designed to recognize individual differences and determine where a person fits within this typology. Myers and Briggs added a fourth dimension, approach to structure. These four dimensions and their bipolar opposites are summarized in Table 1.

Table 1. MBTI Measures - 4 Dimensions with 8 factors		
Perception – Ways of Gathering Information	Sensing	Intuition
Judgment – Ways of Making Decisions	Thinking	Feeling
Differences in Orientation	Extraversion	Introversion
Different Approaches to Structure	Judgment	Perception

As can be seen from Jung's theory, the goal is to measure a person's abilities and preferences and not their specific behavior. Now, we will discuss each of Jung's four personality dimensions in greater detail.

PERCEPTION – SENSING VERSUS INTUITION

This dimension describes two opposing ways of gathering information. Individuals who prefer to gather information through sensing focus on what is actually present. As the label implies they tend to use information that is available to the senses. They trust their own personal experiences and focus on what is real and concrete in the here and now. By contrast, individuals who prefer intuition as an information gathering approach focus more on implications and inferences. They are oriented toward the future and tend to anticipate events. Intuitive information gatherers prefer to focus more on the abstract and theoretical, using the current information to project future possibilities.

JUDGMENT – THINKING VERSUS FEELING

Judgment is characterized as how people interpret and organize information in order to make decisions. Thinkers are more logical in their perspective as they tend to use an analytical approach to problem solving. They analyze and weigh the evidence to come up with objective decisions. Conversely, individuals who prefer making judgments based on feeling, introduce their own values into the decisionmaking process. Their decisions tend to be based more on how much they care or what they feel is right. They value the opinions of others and tend to be empathetic toward others' situations.

DIFFERENCES IN ORIENTATION – EXTRAVERSION VERSUS INTROVERSION

Differences in orientation refer to whether a person looks primarily inward for ideas, values and experience or to the external world for these things. Individuals preferring introversion tend to gather information and reflect on it before arriving at decisions. Their outward personality may appear "contained and reserved". At the opposite end of the spectrum, individuals having an extraverted orientation like processing their thoughts out loud and discussing possible alternatives before arriving at a decision.

DIFFERENT APPROACHES TO STRUCTURE – JUDGMENT VERSUS PERCEPTION

This dimension refers to how "people like to organize their external environment". Judgment oriented individuals tend to like their worlds to be orderly, planned and scheduled. They tend to make both short-term and long-range plans and prefer to stick to their plans. By contrast, individuals with a perception orientation, prefer an open and unstructured environment. They view goals as constantly changing as they gather new information.

MBTI IN MANAGEMENT RESEARCH

There have been numerous studies exploring the relationship between psychological types, as measured by the MBTI, and managerial attributes. In their analysis and review of the management literature related to this topic, Gardner and Martinko, 1996, found 35% to be of a predictive-analytical/non-experimental nature and 31% to be of a predictive-analytical/experimental nature. The remaining studies analyzed were descriptive in nature. Based on their review and meta-analysis of the management literature, Gardner and Martinko were able to put forth several propositions regarding the relationship between personality traits as measured by the MBTI and managerial behavior and effectiveness. However, they also discussed limitations of the MBTI, including the need to study situational moderators of behavior and the fact that the measures are bipolar rather than continuous. In general, while the MBTI was shown to be beneficial in analyzing managerial behavior and effectiveness, there is a need to expand the scope of studies to include a wider range of issues (Gardner & Martinko, 1996). As stated by Gardner & Martinko, 1996, "It is clear that efforts to detect simplistic linkages between type preferences and managerial effectiveness have been disappointing." These authors recommend that future studies adopt a "contingency perspective to determine the functions, roles, organizational levels and situations under which particular types excel."
The next section includes a discussion of Churchman's inquiring modes and how an individual's particular mode of inquiry plays a role in determining their pattern of interacting within the environment.

CHURCHMAN'S INQUIRING MODES

In his book *The Design of Inquiring Systems*, Churchman states "…knowledge resides in the user and not in the collection. It is how the user reacts to a collection of information that matters" (Churchman, 1971). Based on this premise, two people could be privy to the exact same "collection" of information and come up with two entirely different ideas. Their interpretation of information, their style of thinking or "inquiry mode" if you will, acts as a filter to how they perceive and act on the given information. Commenting on Churchman's Inquiring Systems, Mitroff, 1973, points out that the act of examining a problem is to "conduct an inquiry

into its very nature" and gather information about it. Because of this, information cannot be separated from inquiry because "what" we know about a problem is not independent of "how" we obtained that knowledge or information. Therefore, a given system of inquiry will not only impact how information is produced, but what is even regarded as information. "Churchman defines inquiry as the activity which produces knowledge, and knowledge as the ability to adjust behavior to changing circumstances. In other words, knowledge is the ability to react to and find solutions for the problems we create and encounter" Vandenbosch, etal (2001). Therefore, a person's particular mode of inquiry will have a significant impact on how they operate within their environment. "In experimental situations, a subject's way of doing things tends to overshadow what is considered to be the best way, in spite of clear advice and specific training" (Connolly & Thorn, 1987).

Churchman identified five modes of inquiry based on the notions of five philosophers, Leibniz, Locke, Kant, Hegel and Singer. Each inquiring system does not depict an exact account of how each philosopher conceived the theory of knowledge; instead, it takes their basic ideas and represents them in the language of the design of an inquiring system (Churchman, 1971). Following is a discussion of these inquiring systems defined by Churchman.

LEIBNIZ

"Leibnitzian inquiring systems are the archetype of formal deductive systems" emphasizing the "purely formal, the mathematical, the logical and the rational aspects of human thought" (Mitroff, 1973). Leibnizians look internally, valuing what they already know. They are fact seekers and work within "fact nets". As new facts are discovered, Leibnizians assimilate the new information into what they already know and evaluate it accordingly. They do not like contradiction and continually search for the "right answer" as Leibnizians believe that a right answer always exists. They are slow to change (Vandenbosch, 2001). Much of the "practice of science can be viewed as a Leibnizian inquirer". "Scientists have a tendency to resist changes in their basic outlook on the world". They give much more credence to new findings that can be linked to prior findings (Churchman, 1971). These types of thinkers don't try to differentiate accurate from false facts because they assume that false fact nets will shrink. In terms of the practice of science, they try to tie findings to theory. Leibnizians tend to take control and direct others, expressing their strongly held points of view. Churchman's examples of artificial intelligence machines which parallel Leibnizian methods of processing include algorithm machines, heuristic search machines and theorem-proving and problem-solving machines. Regarding the five "styles of thinking" defined by Harrison and Bramson (1982), Leibnizian inquirers are analogous to the Analyst's style of thinking. "The Analyst sees the world as logical, rational, ordered and predictable" (Harrison and Bramson, 1982).

LOCKE

Inquiring system that are Lockean in nature can be considered the archetype of "experiential, inductive, consensual systems", emphasizing the "purely sensory, empirical aspects of human knowledge" (Mitroff, 1973). Lockean inquirers are primarily concerned with consensus. Although they may not be considered generators of ideas, they ask others for their ideas. Lockeans are not necessarily opposed to change, but will not attempt to change their environment unless it will create harmony and unanimity (Vandenbosch, 2001). These types of thinkers have no preconceptions, but receive input and categorize it much like a filing system (Churchman, 1971). However, they do not build on their internal ideas as Leibnizians do. Because of the value they place on consensus, they are heavily influenced by those around them. Information acquired is only used if approved by the group (Vandenbosch, 2001). The analogous style of thinking for a Lockean is the Realist. Whereas "the analyst is deductive and analytical, the realist is inductive and empirical" (Harrison and Bramson, 1982).

KANT

Kantian inquiring systems are the "archetype of synthetic multimodel systems", characterized by representations, emphasizing "both the formal and empirical – the integrative--aspects of human thought" (Mitroff, 1973). They make use of a network of information sources and their search for knowledge is broad. Whereas Lockeans are concerned with consensus, Kantians place value on objectivity. They welcome conflicting viewpoints and accept inconsistencies and varying perspectives. Kantians see change as progress and are quite willing to discard their mental models, replacing them with new ones when additional information proves their older models to be obsolete. When working with others, their goal is to find an appropriate problem resolution rather than win over their colleagues. The style of thinking most associated with the Kantian mode of inquiry is the Idealist. Idealists take a broad view of the world and have a tendency to be future oriented and goal setters. They are likely to pay attention to the needs of people and what is good for them (Harrison and Bramson, 1982).

HEGEL

Hegelian inquiring systems are the "archetype of conflictual, synthetic systems" emphasizing the "antagonistic, the antithetical, the conflictual aspects of human thought" (Mitroff, 1973). Hegelian thinkers are dialectic in that they see "debate between different worldviews as the only way to develop theses and antitheses to arrive at a synthesis that accommodates both worldviews" (Carugati, 2004) From their perspective, conflict is seen as a creative process. They believe better solutions emerge from debate and the dialectic process. Because of this, they tend to think "beyond the boundaries of standard rules and approaches"

(Vandenbosch, 2001). While Kantians are concerned with objectivity, Hegelians use values, beliefs and emotions as well as logic. Their inquiry takes place through "strong internal debate". Because of this, they may have a harder time reaching a decision. "Hegelians challenge the designer to give up the explicit" (Churchman, 1971). Their style of thinking is that of the Synthesist. "Synthesists enjoy speculative, philosophical, intellectual argument, so long as it doesn't get too somber and the silliness of the act of argument itself is acknowledged". They "see the world as constantly changing and they welcome that view" (Harrison and Bramson, 1982). At times their digressions appear to have no relevance to the topic at hand, but in fact, that relevance is usually present if one listens closely.

SINGER

Singerians possess characteristics from all of the systems of inquiry. Singerian inquiring systems are the "archetype of synthetic interdisciplinary systems emphasizing richly diverse modes of human thought: the scientific, the ethical, as well as the aesthetic" (Mitroff, 1973). "They are characterized by frequent, dramatic and unpredictable change" (Vandenbosch, 2001). This is the most flexible and adaptive inquiry mode. Singerians attempt to find the "optimum mix between commitment to a problem and detachment, between passion for it and reflection about it and between deferral and immediacy (Vandenbosch, 2001). They are constantly evaluating and never take anything for granted. Singerians' style of thinking is that of the Pragmatist. "The Pragmatist excels at finding new ways of doing things with the materials at hand" and have the motto "whatever works". They are characterized by the contingency approach in that they look at what will work best depending on the situation at hand. Pragmatists tend to be good tactical planners, taking things one step at a time (Harrison and Bramson, 1982).

As illustrated, Churchman's five modes of inquiry represent five fairly distinct styles of thinking. They differ from the MBTI in that they describe a person's particular style of thinking as opposed to specific aspects of personality. In 1977, the InQ (Inquiry Mode Questionnaire) was developed by Harrison, Bramson, Bramson and Parlette, as a mechanism for exploring differences in and characterizing an individual's thinking style.

The next section reviews the characteristics of agile managers, categorizing them into five distinct dimensions related to behavior.

CHARACTERISTICS OF AGILE MANAGERS

In the preceding discussion on the role of agile managers, responsibilities of managers within an agile environment were identified. Each of these responsibilities can be categorized as falling into one of the following dimensions related to an individual's behavior: Interaction

Style, Innovation/Exploration Propensity, Approach to Change, Information Acquisition Mode and Visionary Ability.

INTERACTION STYLE

This dimension is associated with how an individual relates to others and is one of the most critical areas for agile management. It includes most of the traits pertaining to coaching and leadership. A person with a controlling Interaction Style has the tendency to direct others versus a collaborative style in which they work side by side with others to jointly come up with the best solution (Vandenbosch, 2001). The Interaction Style which best describes agile managers includes activities and attitudes related to:

believing in and trusting people to do a good job (Beck, 2000; Cockburn, 2001; Highsmith, 2001)
motivating team members to work outside the norm (Highsmith, 2004)
providing continual guidance (incremental versus policy manual up front) (Beck, 2000)
expediting connections between people and teams (Highsmith, 2001)
influencing and inspiring versus coercing (Cockburn, 2001; Highsmith, 2004)
facilitating group decisions (Cockburn, 2001)
causing things to be done (behind the scenes) versus authoritarian control (Jeffries, 2001)
intervening when necessary (Beck, 2000).

INNOVATION/EXPLORATION PROPENSITY

Innovation/Exploration Propensity refers to an individual's tendency to look outward and investigate new ideas that challenge the norm; to look "outside of the box" for new and creative ways to solve problems. This includes not only working outside the norm but encouraging others to explore while providing boundaries within which innovation can flourish (Highsmith, 2004). Agile managers display a high propensity for innovation and exploration.

APPROACH TO CHANGE

An individual's approach to change describes how they view and handle change. Possibilities for this dimension can range from resisting change (maintaining the status quo) to welcoming and even initiating change (Vandenbosch, 2001). Agile managers encourage and embrace change. They see it as an opportunity to help the customer respond to the turbulence of the marketplace and as an open door to innovation (Highsmith, 2002). It is also the agile manager's role to encourage their team members to welcome change (Chin, 2004; Highsmith, 2004).

INFORMATION ACQUISITION MODE

The manner in which a person seeks to obtain data can be characterized as their Information Acquisition Mode. For example, an individual may search for specific kinds of information, perhaps seeking only data confirming their point of view (searching with a pre-determined agenda and focus (Vandenbosch, 2001)). Conversely, another individual may approach information acquisition as an opportunity to gather data that is very different from their own experiences maybe even seeking conflicting viewpoints (scanning for information with a broad agenda and view (Vandenbosch, 2001)). As mentioned earlier, agile managers need to have an outward-facing mentality, constantly scanning the external environment for factors affecting their environment (Chin, 2004). They should also be continual learners, who lead by example, strive to learn about their customers' needs, team or personality conflicts, new technologies and the most current information regarding best practices in agile methods (Krievsky, 2002).

VISIONARY ABILITY

An individual's Visionary Ability is defined as how well they are able to look ahead and envision or imagine the desired future state. A person with Visionary Ability can look past "what is" and envision "what can be" as well as set goals and direction, sharing this vision with others. In order to guide the project and ensure that it stays on course making the appropriate changes when necessary, an agile manager should possess the capability to look to the future, creating vision and setting direction (Highsmith, 2001). Agile managers must be able to set goals and constraints, share the vision with their team members and provide an environment conducive to achieving those goals (Cockburn, 2001).

Next, the information covered thus far will be used to construct a table mapping these characteristics to Churchman's modes of inquiry.

INQUIRY MODES OF AGILE MANAGERS

The following table takes the dimensions described above and evaluates them in terms of Churchman's modes of inquiry. These evaluations are then rated based on their suitability for reflecting behaviors beneficial when managing agile projects. They are rated as either being negative (-), neutral (n) or (+) positive.

Table 2. Mapping of Attributes of Agile Managers to Churchman's Modes of Inquiry					
	Leibnizian	**Lockean**	**Kantian**	**Hegelian**	**Singerian**
Interaction Style	(-) controlling	(n) conciliatory	(+) collaborative	(n) dialectic, but debates internally	(n) inconsistent/ unpredictable
Innovation/ Exploration Propensity	(-) look internally for answers	(-) receive input and categorize	(+) broad search; will change mental models accordingly	(+) think beyond boundaries of standard rules	(+) excels at finding new ways of doing things
Approach to Change	(-) slow to change	(n) not opposed to change; will initiate if it supports unanimity	(+) see change as progress	(+) see conflict as creative process; welcome differing views	(+) welcome change; flexible and adaptive
Information Acquisition Mode	(-) searching for *the* "right answer"	(-) searching limited to group approval	(+) broad search for knowledge and multiple viewpoints	(+) search for different worldviews	(+) constantly evaluating new information
Visionary Ability	(-) fact based	(-) fact based	(+) future oriented goal setters	(n) speculative, synthesizing conflicting views, but difficulty making a decision	(-) tactical; take things one step at a time
(+) Positive (n) Neutral (-) Negative					

A positive rating indicates that, for a given dimension, this mode of inquiry is compatible with agile management principles. If the rating is neutral, the inquiry mode for that particular dimension is neither compatible nor incompatible with the tenets of agile management. And, dimensions with a negative rating indicate that, for this specific dimension, the mode of inquiry is incompatible with the assumptions of agile management. Each cell contains a short description explaining the rationale for the rating. These descriptions of inquiring modes were gleaned from the literature on Churchman's inquiring systems.

In general, the Leibnizian and Lockean modes of inquiry appear to be the least compatible with an agile environment. All Leibnizian dimensions are negative and Lockeans have three that are negative and two that are neutral. Kantians appear to be the best candidates for agile management with positives for all dimensions. Hegelians and Singerians both exhibit characteristics that are relatively compatible with agile principles. However, Interaction Style, one of the most important dimensions for agile is neutral for both Hegelians and Singerians.

Perhaps if each dimension was weighted based on its importance to agile management, more insight could be provided. In any case, it is not surprising that the leftmost columns of the table have characteristics that are largely incompatible with agile assumptions because they represent the most rigid and controlling modes of inquiry. In fact, Churchman argues that the five modes of inquiry illustrate an evolution from the primitive forms of inquiry systems to the more advanced (Vandenbosch, 2001). However, what is surprising is the fact that Hegelians and Singerians (theoretically, the "more advanced" and progressive inquirers), are not the best candidates for agile managers. First, as mentioned above, their Interaction Style is rated as neutral. The ideal Interaction Style for agile managers is collaborative. Hegelians tend to debate within themselves rather than working with others and Singerians are unpredictable in their relationships with others. Secondly, in terms of Visionary Ability, Hegelians do speculate and synthesize conflicting views, however because their inquiry takes place through strong internal debate, they may have a hard time making decisions. This difficulty in reaching a decision can impact their ability to decide on a course of action, a necessary prerequisite for setting goals and direction. And, Singerians' Visionary Ability is hampered by their tendency to think tactically. While Leibnizians and Lockeans may be too rigid, Hegelians and Singerians may be too flexible. In order to be a good facilitator, an important role for agile managers, one must be able to work with others while facilitating the decision making process and have the ability to guide the group toward resolution. Hegelians may be able to stimulate debate and group discussion, but never be able to achieve resolution. Singerians' unpredictability can be unsettling to team members looking for leadership and their tendency to think tactically limits their ability to look ahead and effectively guide the team. Therefore, based on this analysis, Kantians possess characteristics that are most compatible with agile principles. The Kantian mode of inquiry represents a balance between too much rigidity and too much flexibility. And, while flexibility may be a hallmark of agility, too much flexibility can cause lack of direction.

MBTI VERSUS INQUIRING MODES

As can be seen from the above analysis, Churchman's five modes of inquiry provide a good framework for analyzing the various behavioral dimensions related to desirable agile leadership requirements. In this section each of the five behavioral dimensions will be discussed as they relate to the MBTI.

INTERACTION STYLE

An individual's interaction style could be related to the differences in orientation described in the MBTI. However, introversion versus extraversion does not map as well into this dimension because either type could exhibit a controlling or collaborative style. Within the

MBTI, the introversion/extraversion factors are more related to whether they act quickly in situations or think over all of the possibilities before taking action. The MBTI does not provide a good measure for this dimension.

INNOVATION/EXPLORATION PROPENSITY

This dimension seems to be related to both the MBTI's orientation as well as approach to structure. Extraverts may tend to look outward and explore more while introverts may have a tendency to look inward. Regarding approach to structure, those with more of a perceiving view may be more innovative versus the judging individual who prefers structure and wants to obtain closure as quickly as possible. This desire to obtain closure may limit their ability to explore sufficiently. Therefore, both of these dimensions of the MBTI may aid in determining an individual's innovation/exploration propensity.

APPROACH TO CHANGE

This particular dimension appears to map most directly to the approach to structure. Judgment focused individuals like their environments to remain stable whereas perceivers are more flexible and open to change.

INFORMATION ACQUISITION MODE

Perception is defined as characterizing how an individual gathers information. Therefore, it would appear directly related to information acquisition mode. And, the judgment dimension of MBTI (thinking or feeling) will have an effect on how the information is "filtered" as well.

VISIONARY ABILITY

Visionary ability seems somewhat related to perception as it is characterized as either looking at the information that is currently available versus basing decisions on a "theoretical projection of future possibilities".

While relationships can be found between dimensions of the MBTI and dimensions related to agile leadership, the relationship is not as clearcut as the Inquiry Modes approach. Perhaps the Inquiry Modes approach is more compatible with predicting behavioral dimensions because the InQ instrument measures an individual's style of thinking rather than specific aspects of personality.

SUMMARY AND CONCLUSIONS

This paper sought to introduce an approach to assessing an individual's propensity for leadership success in an agile software development environment. In doing so, the MBTI, a popular approach for assessing personality profiles was also considered. This analysis suggests that an inquiring systems perspective using the InQ to measure an individual's style of thinking may provide a useful tool, (perhaps better than the MBTI), in predicting an individual's likelihood to succeed in managing project teams in an agile environment.

FURTHER RESEARCH

By analyzing desirable characteristics of agile managers within the context of Churchman's modes of inquiry, this paper provided some insight into the types of managers most likely to be successful in an agile environment. However, this is only from a theoretical perspective and empirical research to test these propositions is warranted. One potential experiment would be to administer the Inquiry Mode Questionnaire (InQ Educational Materials, 2004; developed by Harrison and Bramson, to determine an individual's thinking style) to a pool of subjects consisting of managers in both traditional and agile environments. In addition to the InQ, these managers would be given a survey designed to determine their level of managerial effectiveness. The results of the management success survey could be analyzed in relation to their identified modes of inquiry to investigate the presence of correlations between their modes of inquiry, management environments and managerial effectiveness. Another experiment to examine these dimensions from an inquiring modes perspective involves testing for them independently. Subjects would take the InQ test and then perform various tasks in specific situations designed to measure each of the dimensions. The resulting scoring of the dimensions would be mapped to the modes of inquiry to determine if they align with those proposed in the aforementioned table.

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STATISTICAL POWER FOR DETECTING SINGLE STRATUM SHIFT IN A MULTI-STRATA PRODUCTION PROCESS

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ABSTRACT

In spite of institutionalization of statistical process control programs in U.S. industry to improve quality, many companies still experience problems in implementing them. This is especially the case for multi-strata (population) production processes. Under statistical control, if any stratum drifts away from the target due to an assignable cause, such shift must be detected at the earliest (with a high degree of sensitivity) and corrective actions taken to ensure quality output. This paper investigates the sensitivity of detecting a single stratum shift from the target for a stratified production process. Selection of an appropriate sampling method is proposed to have a strong bearing on the relative sensitivity of detecting shift in a single stratum. Monte Carlo simulation technique is used to develop power curves for the above mentioned process under stratified and random sampling plans using both $\bar{x}$ and R control charts. The role of process capability in the selection of appropriate sampling method is also examined.

Keywords: Stratified, Random, Power Curve, Control Charts, Monte Carlo Simulation

INTRODUCTION

Many manufacturing firms still suffer from poor quality of manufactured goods in spite of using quality control charts for over a decade. These firms continue to face challenges in implementing quality programs due to difficulties in correctly applying the statistical process control (SPC) techniques to their processes. Given that a control chart's function is to monitor a production process, selection of an appropriate sampling method is crucial for the charts to function effectively. It is critical that the chart detects changes in process as soon as possible (with a high degree of sensitivity) after they occur, especially for processes that are barely capable of meeting the specifications [Caulcutt, 1995; Evans, 1993]. Osborn (1990) states that an insensitive control chart may miss out in detecting small shifts in a process and jeopardize a company's continuous improvement efforts. Thus, a chosen sampling method can be termed appropriate if it enables control charts to detect process shifts with greater sensitivity without generating excessive false alarms [Osborn, 1990; Wheeler, 1983].

The problem of choosing appropriate sampling method is straight-forward when a production process consists of just one population (stratum). The control charts ($\bar{x}$ and R) would be based on a rational sample selected from successive time periods of production [Grant, 1988; Wadsworth, 1986]. In certain chemical and pharmaceutical applications the production process may consist of multiple fill-heads, thus producing a mix of populations (strata). When applying quality control techniques to monitor such process, the choice of an appropriate sampling method is not so easy. For example, a four cavity machine could be producing four distinctly different populations (strata) and the choice of different sampling methods would affect the sensitivity of detecting a shift in one or more strata. Most often, whichever is "simplest", "most convenient", or "seemingly logical" is used to determine the sampling method [Caulcutt, 1995; Mayer, 1983; Osborn, 1990; Squires, 1982].

In the past, most literature has focused on studying different aspects of process shift for production processes producing only one population. The seminal studies by Scheffe (1949) and King (1952) develop operating characteristic (OC) curves for $\bar{x}$ and R charts, when samples are rational and process standards are given. Olds (1961) investigates power characteristics of control charts for detecting process shifts in the context of rational sampling for both the "no standard" and "standard given" cases. Costa (1997) shows that the $\bar{x}$ chart with variable sample size and sampling intervals is more sensitive than the traditional $\bar{x}$ charts in detecting even moderate shifts in the process. Osborn's (1990) work emphasizes the importance of "statistical power" to a QC practitioner's ability in detecting a particular shift in the process average and laments its lack of understanding among practitioners who utilize process control techniques. He also emphasizes the role of sample size in enhancing the statistical power of control charts. The work by Davis et al. (1993) improvises on the explanation of the "statistical power" of a $\bar{x}$ control chart as used by Osborn (1990). Unlike any previous study, Palm (1990) and Wheeler (1983) present tables of the power function for the $\bar{x}$ chart using multiple detection rules for the mean process shift.

The literature focusing on process shifts for production systems producing multiple populations is still limited. Ott and Snee (1973) present three different methods of analysis - plots of raw data, residuals methods, and analysis of variance method – to examine fills of individual heads in a multiple fill-head machine. Montgomery (1982) proposes use of group control charts for detecting process shifts when the multiple population streams are not highly correlated. The work by Mortell and Runger (1995) suggests using a pair of control charts, Shewart and CUSUM charts, to monitor multiple stream processes. Runger et al. (1996) propose using multivariate techniques to detect assignable causes for processes with multiple population streams. Lanning et al. (2002) use adaptive fractional approach to monitor processes with a large number of population streams. Even though the above studies present different statistical methods to monitor a multi strata process, none of them examine the comparative effect of alternate sampling methods on the sensitivity of detecting a process shift.

The objective of this paper is to investigate the comparative sensitivity of detecting a process shift in a multi-strata production process under random and stratified sampling methods. Power curves are used to depict the sensitivity of detecting process shifts. This paper uses Monte Carlo simulation to develop power curves under alternate sampling methods using both $\bar{\times}$ and R control charts. The resulting power curves can be important decision tool for a QC practitioner in selecting the appropriate sampling method.

CONTROL CHARTS UNDER RANDOM AND STRATIFIED SAMPLING

Consider a production process that consists of four different fill-heads to fill a batch of four vials at a time to a specified weight. After a batch of four vials is filled, it is replaced by another batch of four vials. This represents a scenario where the measurements come from four different strata. It is desired to determine if a random or stratified sampling plan would best assist in designing a control system for this production process. For example, in designing a process control system utilizing $\bar{\times}$ and R charts, would it be better to sample four vials at random from the process or sample one from each fill-head for a total of four.

A sample for this process is "random" when the vials from different populations are mixed together forming a "pool of mixed product", and random samples of n vials are taken over time. Under this plan, it is important to make sure that the vials output between time intervals is large enough so that all combinations of possible samples from the four fill-heads are equally likely. That is, the sample could consist of four vials from a single fill-head or any other combinations of fill-heads. After N such samples are taken, $\bar{\times}$ and R charts would be determined and the question of whether or not the process is in a state of statistical control answered. If the answer to this question is "yes", then these control charts would be used to monitor the process.

A sample is considered "stratified" when each succeeding sample consists of four measurements, one from each population at specified intervals of time [Burr, 1979; Grant, 1988]. If all strata are identical populations, conventional control charts would act as if the stratified sample was a random sample from that common population. However, if the different strata have different means, conventional control charts should indicate this stratification problem that can be fixed using either one of the following three approaches: 1) Adjust the bias (as proposed by Burr & Weaver, 1949; Westman & Lloyd, 1949) which involves adjusting the data of each strata by the difference between the grand mean and the mean of the corresponding strata to scale down R, thus providing overlapping probability distributions for all the strata with a common target mean; 2) Monitor each strata separately which involves developing separate control charts for each strata; and 3) Fix strata to common mean which involves adjusting the fill heads or the process physically to a common mean value.

The remaining sections of this article will assume that either the different strata are identical initially or upon detecting a stratification problem are fixed in accordance with cases 1 or 3 above. Even if the process is concluded to be in-control, not only is a shift in all populations

possible but a shift in a single stratum very likely to occur. It is very crucial for a QC practitioner to detect this shift as early as possible. Thus, this paper focuses on addressing the important question, which sampling method (random or stratified) would be more sensitive in detecting this shift of the single stratum. The next section develops power curves for R and $\bar{\times}$ charts to compare the relative sensitivity of each sampling plan (random and stratified) in detecting the shift in a single stratum.

POWER CURVES

If a multi-strata in-control production process is suddenly affected by an assignable cause, it may cause a single stratum to shift above or below the target value. When this happens, it becomes important to detect this shift with a high degree of sensitivity.

Power curves are useful graphical tools that represent the statistical power (sensitivity) of detecting a process shift of a specified magnitude by the first subgroup taken following the shift [Osborn, 1990]. The vertical axis of the power curve provides the probability of rejection (out of control indication) corresponding to a given shift in the process mean of a single strata.

The following notations have been used to develop the power curves.

n = Sample size
N = Size of each strata
$\bar{\times}$ = Sample mean
R = Sample range
s = Number of strata in the process
δ = A real no. indicating the magnitude of mean shift as a multiple of Standard Deviation
σ_x = Standard deviation of each strata (Assumed to be equal)
T = Target or initial mean of each strata (assuming they are equal or have been fixed in accordance with cases 1 or 3)
P_L = P(R or $\bar{\times}$ < LCL)
P_U = P(R or $\bar{\times}$ > UCL)
P_m = Probability of a sample mean greater than UCL or less than LCL = $P_L + P_U$
P_R = Probability of a sample range greater than UCL or less than LCL = $P_L + P_U$

At this point it should be noted that the power curves developed in this paper are based on one control chart for all four fill-heads. Although four different control charts for four different fill-heads will detect a single stratum shift quicker, multiple charts tend to pose certain disadvantages. According to Mortell and Runger (1995), multiple charts not only increase the opportunities for false alarms but under certain circumstances make it difficult for individual charts to detect an assignable cause affecting a single stratum. Most practitioners suggest using either - (a) one chart where the sample contains one observation from each stratum or (b) one

chart where the sample is selected from the pooled production of all strata. In the next section, power curves for both R and $\tilde{x}$ charts using Monte Carlo simulation are developed under alternate sampling plans.

POWER CURVES FOR R AND $\bar{x}$ CHARTS UNDER STRATIFIED SAMPLING

Assume that the process is in a state of statistical control and the mean of each probability distribution of four fill-head populations in the process is T with standard deviation σ_x. The LCL and UCL for the R-chart can be shown to be $D_3\overline{R}$ and $D_4\overline{R}$ (where D_3 and D_4 are constants depending on the sample size) respectively and for the $\bar{x}$-chart to be $T \pm 3\sigma_x/\sqrt{n}$ for n=ks where k represents the number of replicated sets of one observation taken from each of s strata. Without loss of generality, the standard normal distribution with T=0 and σ_x=1 will be used for the purpose of simulation.

LCL AND UCL VALUES FOR THE R-CHART

As stated earlier, the control limits for the R-chart are given by:

$$LCL = D_3\overline{R} \quad \text{and} \quad UCL = D_4\overline{R} \tag{1}$$

On substituting
$\overline{R} = \sigma_x.d_2$, in (1) we get:

$$LCL = D_3.\sigma_x.d_2 \text{ and } UCL = D_4.\sigma_x.d_2 \tag{2}$$

where σ_x=1 for standardized normal random variate.

Since $D_3 = 0$, $D_4 = 2.282$, and $d_2 = 2.059$, for n=4, from the quality parameter table in Grant et al. [5], we get the control limits as:

$$LCL = 0 \text{ and } UCL = 4.698 \tag{3}$$

LCL AND UCL VALUES FOR THE $\bar{x}$-CHART

The control limits for the $\bar{x}$-chart are given by $T \pm 3\sigma_x/\sqrt{n}$. It can be shown that for the standard normal random variable (Z) with a mean of 0 and a standard deviation of 1, the control limits are given by:

$$LCL = - 3/\sqrt{4} = -1.5 \quad \text{and} \quad UCL = 3/\sqrt{4} = 1.5 \qquad (4)$$

The control limits for the R and $\bar{\bar{x}}$ charts given by equations (3) and (4) respectively will be used to determine the probability of rejection for developing power curves.

Now, if the mean of a single stratum shifts by ($\delta\sigma_x$) above or below the mean (T), the analytical expressions for a new common mean and standard deviation for the R-chart are difficult to develop since the statistical sampling distribution for range (R) is unknown. Hence, we propose to use Monte Carlo simulation to calculate the probability of detecting this shift in one stratum by both R and $\bar{\bar{x}}$ charts.

To perform Monte Carlo simulation for the above scenario, a software package, Insight.xla (Business Analysis software for Microsoft Excel), is used. The three step approach that the software requires to perform the Monte Carlo simulation for stratified sampling plan is as follows:

Step 1: Build model for s=4 different strata

The fill values for each of the three strata in a state of statistical control were generated using a random number generating function, gen_Normal (0,1). This function randomly generated standardized normal values (z) with a mean of 0 and a standard deviation of 1 for each of the three strata. For the fourth stratum whose mean shifted by $\delta\sigma_x$, the corresponding function used was, gen_Normal (δ, 1), where $0.5 \leq \delta \leq 10.5$. Formulae for calculating the *Mean* and *Range* values for the four strata were incorporated in the worksheet.

Step 2: Specify simulation setting

The primary simulation setting that the software requires is the "number of trials". The number of trials was determined by asking the question - what sample size would enable the determination of the probability (proportion) of rejection (P) to within 0.005 with 95% confidence for the overlapping probability distributions of all the four strata. Knowing that the probability of an out of control indication is approximately 0.003 for both the $\bar{\bar{x}}$ and R control charts for an in-control process, a sample size of 2000 would allow an estimate for the probability of out of control indication within ± 0.0024 with 95% confidence.

Step 3: Run simulation and examine results

It is assumed that the mean of the fourth stratum shifts by $\delta\sigma_x$ such that $0.5 \leq \delta \leq 10.5$. The shift values (δ) are considered in increments of 0.5. A simulation run for 2000 trials was performed for each shift (δ) value and the resulting values for R and $\bar{\bar{x}}$ recorded.

After comparing the R values obtained in Step 3 with the control limits for the R-chart (LCL_R= 0, UCL_R= 4.698) and $\bar{\bar{x}}$ values with the control limits for the $\bar{\bar{x}}$-chart ($LCL_{\bar{\bar{x}}}$= -1.5, $UCL_{\bar{\bar{x}}}$= 1.5), the proportion of values falling below LCL (P_L) and above UCL (P_U) were determined for each chart.

Table 1 shows the P_m, P_R, and P values for $\bar{\bar{x}}$ and R charts under stratified sampling for different values of δ. Figure 1 shows the power curves for both R and $\bar{\bar{x}}$ charts under stratified sampling.

Table 1: Rejection Probabilities for $\tilde{}$ and R charts under Stratified Sampling Plan

	$\tilde{}$ chart			R-chart			Total
.	P_L	P_u	$P_m = Pu + P_L$	P_L	P_u	$P_R = Pu + P_L$	P
0.5	0.0010	0.0010	0.0020	0	0.0070	0.0070	0.0090
1	0.0005	0.0055	0.0060	0	0.0115	0.0115	0.0174
1.5	0	0.0120	0.0120	0	0.0365	0.0365	0.0481
2	0	0.0245	0.0245	0	0.0635	0.0635	0.0864
2.5	0	0.0360	0.0360	0	0.1370	0.1370	0.1681
3	0	0.0750	0.0750	0	0.2615	0.2615	0.3169
3.5	0	0.1105	0.1105	0	0.3820	0.3820	0.4503
4	0	0.1690	0.1690	0	0.5295	0.5295	0.6090
4.5	0	0.2375	0.2375	0	0.7030	0.7030	0.7735
5	0	0.2970	0.2970	0	0.8225	0.8225	0.8752
5.5	0	0.4000	0.4000	0	0.9090	0.9090	0.9454
6	0	0.4930	0.4930	0	0.9545	0.9545	0.9763
6.5	0	0.6100	0.6100	0	0.9825	0.9825	0.9932
7	0	0.6910	0.6910	0	0.9940	0.9940	0.9981
7.5	0	0.7765	0.7765	0	0.9965	0.9965	0.9992
8	0	0.8370	0.8370	0	1.0000	1.0000	1.0000
8.5	0	0.9005	0.9005	0	1.0000	1.0000	1.0000
9	0	0.9395	0.9395	0	1.0000	1.0000	1.0000
9.5	0	0.9610	0.9610	0	1.0000	1.0000	1.0000
10	0	0.9775	0.9775	0	1.0000	1.0000	1.0000
10.5	0	0.9850	0.9850	0	1.0000	1.0000	1.0000

POWER CURVES FOR R AND $\bar{\bar{x}}$ CHARTS UNDER RANDOM SAMPLING

Assume the same initial conditions of the process as given in previous section for stratified sampling. Hence, the initial mean and standard deviation of each of the four fill-head

populations in the process is given by T and σ_x. Monte Carlo simulation is used to determine the sensitivity of both the R and $\bar{x}$ charts in detecting the shift of one stratum mean. The three step approach to run Monte Carlo simulation for random sampling plan is presented next.

Step 1: Build model for s=4 different strata

Recall that the random sample involves selection of items in such a way that all the items in the population of interest have the same probability of being selected. As a result, the probability of a measurement being selected from each of the 4-strata is 0.25. Since the distribution of 3-strata constitutes a common population, it can be shown that for a random sample, the probability of a measurement being selected from the common population is 0.75 and that from the distribution of the shifted stratum is 0.25. Hence, a random sample of size 4 was generated by incorporating a logical random number generating function, *IF Rand () > 0.25, gen_Normal (0,1), gen_Normal (δ,1),* in 4 different cells of the worksheet.

This would ensure that all the 4 measurements in the random sample come from one or any combination of the 4-strata. The formulae to keep track of the *mean* and *range* of the random samples were also incorporated in the worksheet.

Steps 2 and 3: These steps were same as given under stratified sampling.

The proportion of R and $\bar{x}$ values obtained using Monte Carlo simulation which fall outside the LCL (P_L) and UCL (P_U) for R and $\bar{x}$ charts respectively were determined.

Table 2 shows the P_L, P_U, and P values for R and $\bar{x}$ charts under random sampling plans for different values of δ. Figure 1 also shows the power curve for $\bar{x}$ and R charts under random sampling plan.

DISCUSSION

The power curves in Figure 1 show the relative sensitivity of detecting a shift in the mean of a single stratum by R and $\bar{x}$ charts under stratified and random sampling methods.

POWER CURVES FOR R-CHART

For both stratified and random sampling methods, the R-chart is found to be more sensitive than the $\bar{x}$-chart in detecting the shifts of different magnitude in the mean of a single stratum. For example, under stratified sampling method, if a stratum mean shifts by $3\sigma_x$, its probability of detection is 26.15% by the R-chart as compared to 7.50% by the $\bar{x}$-chart. However, under random sampling method, both R and $\bar{x}$ charts are equally sensitive in detecting

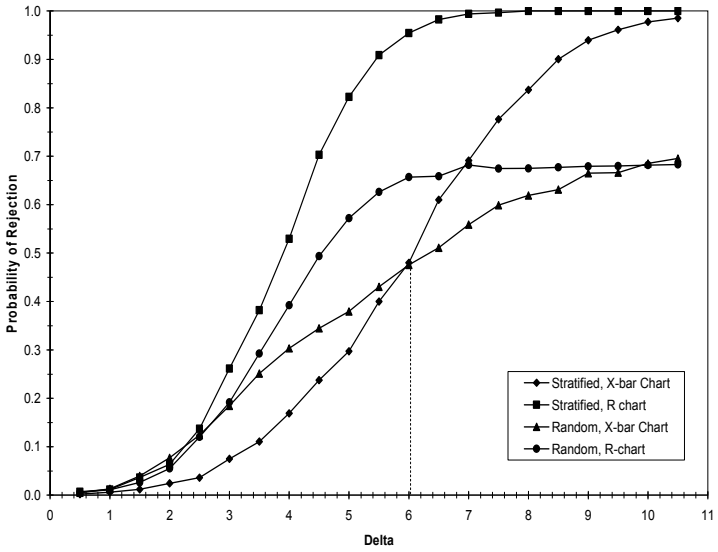
single stratum shifts up to $3\sigma_{x.}$ For shift values (δ) > $3\sigma_x$, the R-chart is relatively more sensitive than the $\bar{\bar{x}}$-chart.

Table 2: Rejection Probabilities for $\tilde{}$ and R charts under Random Sampling Plan							
$\tilde{}$ chart				R-chart			Total
.	PL	Pu	Pm =PL+Pu	PL	Pu	PR =PL+Pu	P
0.5	0.0015	0.0035	0.0050	0	0.0060	0.0060	0.0110
1	0.0005	0.0125	0.0130	0	0.0110	0.0110	0.0239
1.5	0.0000	0.0395	0.0395	0	0.0260	0.0260	0.0645
2	0.0010	0.0760	0.0770	0	0.0550	0.0550	0.1278
2.5	0.0000	0.1240	0.1240	0	0.1200	0.1200	0.2291
3	0.0005	0.1840	0.1845	0	0.1915	0.1915	0.3407
3.5	0.0005	0.2506	0.2511	0	0.2925	0.2925	0.4702
4	0.0005	0.3026	0.3031	0	0.3923	0.3923	0.5765
4.5	0.0005	0.3440	0.3445	0	0.4937	0.4937	0.6681
5	0.0000	0.3794	0.3794	0	0.5720	0.5720	0.7344
5.5	0.0008	0.4297	0.4305	0	0.6263	0.6263	0.7872
6	0.0008	0.4748	0.4756	0	0.6568	0.6568	0.8200
6.5	0.0002	0.5108	0.5110	0	0.6588	0.6588	0.8332
7	0.0000	0.5586	0.5586	0	0.6820	0.6820	0.8596
7.5	0.0005	0.5985	0.5990	0	0.6747	0.6747	0.8696
8	0.0000	0.6190	0.6190	0	0.6750	0.6750	0.8762
8.5	0.0015	0.6295	0.6310	0	0.6770	0.6770	0.8808
9	0.0000	0.6650	0.6650	0	0.6790	0.6790	0.8925
9.5	0.0000	0.6660	0.6660	0	0.6800	0.6800	0.8931
10	0.0005	0.6845	0.6850	0	0.6815	0.6815	0.8997
10.5	0.0005	0.6950	0.6955	0	0.6830	0.6830	0.9035

The R-chart shows higher sensitivity in detecting shifts in a single stratum mean under stratified sampling when compared to random sampling. For example, Figure 1 shows the probability of detecting a $3.5\sigma_x$ shift to be 38.20% and 29.25% under stratified and random sampling methods respectively. It is interesting to note that even though the power of R-chart for detecting a single stratum shift increases with increasing shift (δ) values, this detection power stabilizes for shift levels greater than $7\sigma_x$ under both the sampling methods. For example, the sensitivity of R-chart for detecting shifts (δ) $\geq 7\sigma_x$ stabilizes around 1 under stratified sampling whereas it stabilizes around 68% under random sampling. In summary, if R-chart is the only

tool used by a practitioner to monitor a multi-strata production process, then the stratified sampling method should be preferred over the random sampling method.

Figure 1: Relative Comparison of Detecting Process Shift by $\bar{x}$ and R charts under Stratified and Random Sampling Methods



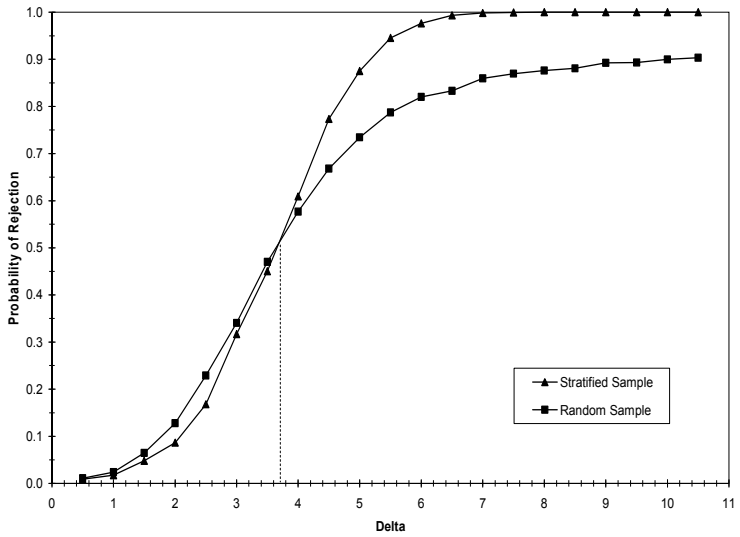
POWER CURVES FOR $\bar{x}$-CHART

Figure 1 also shows that for stratum shifts (δ) $\leq 6\sigma_x$, random sampling is more sensitive than stratified sampling in detecting these shifts. For example, the probability of detecting $3\sigma_x$ shift in the mean of a single stratum under random and stratified sampling is 18.45% and 7.5% respectively. However, for stratum shifts (δ) $> 6\sigma_x$, stratified sampling is found to be more sensitive than random sampling in detecting a single stratum shift. Thus, for a given sample size there exists a threshold shift level below which the random sampling method and above which the stratified sampling method is superior in detecting a single stratum shift. In the above example where sample size is n=4, the threshold shift level occurs at $\delta=6\sigma_x$.

POWER CURVES FOR R AND $\bar{x}$ CHARTS COMBINED

The last column in Tables 1 and 2 represent the total probability of detecting a single stratum shift by R and $\bar{x}$ charts combined under stratified and random sampling respectively. The corresponding power curves are presented in Figure 2.

Figure 2: Sensitivity of Detecting a Process Shift based on $\bar{x}$-bar and R Charts Combined



On considering both the control charts together, random sampling is found to be marginally superior to stratified sampling in detecting single stratum shifts up to $3.5\sigma_x$. This can be attributed to the relative superiority of R chart under stratified sampling when compared to random sampling (see Figure 1) being off-set by that of $\bar{x}$ chart under random sampling. For example, for a $2\sigma_x$ shift in the mean of a single stratum, the probability of detection is 12.78% under random sampling and 8.64% under stratified sampling.

Figure 2 also shows that for the shift level in the single stratum mean such that $\delta=3.5\sigma_x$, both the sampling methods are equally sensitive. We define it as the threshold shift level ($\delta_{threshold}=3.5\sigma_x$) where the relative superiority of R-chart under stratified sampling gets balanced by that of $\bar{x}$-chart under random sampling.

For shift values greater than $\delta_{threshold}$ ($\delta > 3.5\sigma_x$), stratified sampling is found to be more sensitive than random sampling. It is due to the relative superiority of R-chart for stratified sampling plan far exceeding that of $\bar{x}$-chart for random sampling when $3.5 < \delta \leq 6$. Further, for $\delta > 6$, both R and $\bar{x}$ control charts show relative superiority in detecting a single stratum shift under stratified sampling as compared to random sampling.

Theoretically, it can be argued that if both R and $\bar{x}$ charts are used to monitor quality for a stratified production process, then for processes where mean shifts up to $3.5\sigma_x$ do not cause significant quality problems (i.e. processes with higher capability index), a stratified sampling plan should be preferred. For processes with smaller capability index, a random sampling plan would be most desirable.

CONCLUSION

This article has examined the relative superiority of detecting a single stratum shift in a multi-strata process under alternate sampling methods. The results find R-chart to be more sensitive than the $\bar{\bar{x}}$-chart in detecting a single stratum shift under both stratified and random sampling plans. In addition, the R chart shows higher sensitivity in detecting all shift levels in a single stratum mean under stratified sampling than under random sampling method. This research also defines the *threshold* shift level and discusses the impact of process capability index on the relative superiority of the alternate sampling methods in detecting shifts above or below this threshold level.

This research is not the final authority on detecting quality problems underlying a multi-strata production process. It is intended to help QC practitioners gain better insights for selecting appropriate sampling methods that can have differentiating impact in detecting process shifts in a single stratum. While our analysis was based on $\bar{\bar{x}}$ and R control charts, future extensions of this work may wish to investigate appropriate sampling method under special purpose charts like CUSUM or geometric moving average control charts.

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DETERMINANTS OF SURVIVAL OF OPEN SOURCE SOFTWARE: AN EMPIRICAL STUDY

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ABSTRACT

Open Source Software (OSS) has gained notable importance and popularity among users in recent years. This paper uses data of more than 20,000 OSS projects over a 5-year period to investigate the determinants of Open Source Software survival. The results of logistic regressions show that OSS survival probability is positively correlated with general user interest, intensive user interest, and developer effort, but negatively correlated with the restrictiveness of license. Further investigation of the relationships among the determinants indicates that the interest of intensive users has a persistent positive impact on developer effort, while the interest of general users only has a short-term positive impact. It is also shown that projects on Software Development and System Administration have higher probability of survival than projects on other topics.

INTRODUCTION

Open Source Software (OSS) is a new mechanism for creating and developing innovative technologies. The source code of open source software is made freely available so that users can access, modify, and redistribute it. One example of open source software is the Linux operating system. Unlike its rival operating systems, such as Microsoft's Windows and Sun's Solaris, Linux is free in the sense that the source code of Linux is available for downloading from the Internet without charge.

The widespread adoption of OSS by firms and organizations has generated academic interests in understanding various aspects of this phenomenon. One observation is that a large proportion of the projects in the OSS community are inactive. It is important to find out why some projects flourish while a larger number of other projects fail. Past studies on success of OSS include Lerner and Tirole (2002, 2005), Stewart, Ammeter, and Maruping (2006), and Subramaniam, Sen, and Nelson (2009). However, no studies have examined the determinants of survival probability of open source software by comparing survived and failed OSS projects.

In this paper we use logistic regressions to study the determinants of the probability of an OSS project staying active over the five-year period between 2004 and 2009. We find that restrictive license negatively affects OSS survival, particularly for projects about Internet technology. It is shown in the paper that OSS survival is positively correlated with general user interest, intensive user interest, and developer effort. On further investigation of the relationships

among the determinants, we find that the interest of intensive users has a persistent positive impact on developer effort, while the interest of general users only has a short-term positive impact on developer effort. The results show that projects on Software Development and System Administration have higher probability of surviving than projects on other topics. Further analysis shows that projects on Software Development attract more developer effort and general user interest, while projects on System Administration attract the most intensive user interest.

This paper contributes to the literature in two main aspects: First, this paper is the first to use logistic regression techniques to study the determinants of survival, analyzing information of both the survived and the failed OSS projects. Second, using large datasets collected at two points in time over a 5-year period is novel.

The rest of the paper is organized as follows. Section 2 reviews the literature. Section 3 describes the data. Section 4 presents the methods and empirical results. Section 5 concludes.

LITERATURE REVIEW

The literature has explored the factors that contribute to OSS success including developer effort, user interest, license type, technology, ideology, and sponsorship. Stewart, Ammeter, and Maruping (2006) find that attracting developer input and user interest is essential for OSS project success. They show that characteristics of OSS projects including license and type of sponsorship may affect developer motivation and utility to users. Lerner and Tirole (2005) and Subramaniam, Sen, and Nelson (2009) find that the restrictiveness of OSS license has a negative impact on developer interest. However, Subramaniam, Sen, and Nelson (2009) also find that the restrictiveness of OSS license has a positive impact on user interest. Grewal, Lilien, and Mallapragada (2006) find that organizational structure influences OSS project success. Stewart and Gosain (2006) uses developer input and project output (addition of new features and bug fixing) to measure effectiveness. They find that while some ideological components may improve trust and communication and in turn increase effectiveness of OSS team, others may have negative effects on effectiveness.

Most past studies on OSS success take a small sample of OSS projects out of the large number of existing projects. For example, Stewart, Ammeter, and Maruping (2006) use a sample of around 200 OSS projects to study the change in the number of subscribers over 8 months. Grewal, Lilien, and Mallapragada (2006) use a sample of 108 projects and 490 developers to study network embeddedness. Stewart and Gosain (2006) collect data from questionnaires completed by 67 project administrators. Lerner and Tirole (2005) and Subramaniam et al. (2009) use larger samples of OSS projects in their studies. The former conducts a cross-sectional analysis using data collected at one point in time and the latter conducts a longitudinal study using monthly data.

This paper uses logistic regression techniques to understand the determinants of OSS survival. This has not been done by other studies yet. We include in our sample not only the

successful OSS projects but also the failed OSS projects to gain a complete understanding of the whole OSS community. Our data of more than 20,000 OSS projects are collected at two time points over a 5-year period.

DATA

The data were collected from Freshmeat.net at two points in time: 2004/10/07 and 2009/08/17, respectively. Freshmeat maintains a large index of open source software. The total number of projects listed on Freshmeat.net has increased 15%, from 34,804 to 40,194 in the five-year period. Over the five-year period, new projects have been established, while some of the old projects have been removed from Freshmeat. For this study we consider only the projects established before 2004/10/07 and remained on Freshmeat by 2009/08/17. The number of such projects is 22,992.

There are both qualitative and quantitative variables for each of the projects. The qualitative variables include project title, author, license type, programming language, development status, and topic of program. The topic of a program can be Desktop Environment (examples are file managers, window managers, and screen savers), Internet (examples are browsers, HTTP servers, and site management), Software Development (examples are compilers, bug tracking tools, and libraries), and Systems (examples include operating systems, system administration, and networking). The quantitative variables include date added to Freshmeat, date of last update, vitality score, popularity score, rating, and number of subscribers.

Open source projects are released under the terms and provisions of certain licenses. Lerner and Tirole (2002) divide these licenses into three categories: highly restrictive, restrictive and permissive licenses, according to two critical characteristics of the licenses. The first characteristic is whether the license requires that modified versions of the program also be open. The second characteristic is whether the license prohibits the mixing of the open program with other programs that do not employ such a license. In this paper we divide them into two broad categories: restrictive and less restrictive. If a license has both of the above provisions, we call it a restrictive license; if it only has the first provision or neither provision, then it is less restrictive. We explain the types of license in Table 1.

Table 1: License Types

License type	Definition	Examples
Restrictive	Requires that modified versions of the program be open; Prohibits the mixing of open and closed programs.	GPL
Less Restrictive	Requires or does not require that modified versions of the program be open; Allows the mixing of open and closed programs.	LGPL, BSD

The most popular license is General Public License (GPL), a restrictive license. If a project incorporates code under GPL, then this project must also be distributed under the terms of GPL. This is called the "viral" nature of GPL (Feller and Fitzgerald, 2002). In contrast, code released under less restrictive licenses can be incorporated into code released under restrictive licenses without affecting the incorporating project.

Table 2. Descriptive Statistics

	2009 (22,992 projects)	
	MEAN	STD
Added (days ago)	2737	617
Last updated (days ago)	2015	906
Vitality score	5.4	27
Popularity score	94	224
Number of people rating	2	14
Number of subscriptions	20	58

Table 2 lists the means and standard deviations of the quantitative variables. The vitality score for a project is calculated using the equation below:

$$\text{vitality score} = \sqrt{\frac{\text{number of announcements} \times \text{age}}{\text{days since last announcement}}}.$$

From the formula and the variables we obtained from Freshmeat, we can determine the total number of announcements, which is not readily available at Freshmeat. Most announcements are made when there is a new release. We use the number of announcements to measure developer activities.

The popularity score is calculated using the equation below:

$$\text{popularity score} = \sqrt{(\text{number of record hits} + \text{number of URL hits}) \times (\text{subscriptions} + 1)}.$$

The "record hits" is the number of accesses to the project page hosted at Freshmeat, and "URL hits" is the number of accesses for every URL associated with a project that leads off of Freshmeat to the homepage or download site of the project. From these formulas and the variables we obtained from Freshmeat, we can determine the total number of hits (sum of record hits and URL hits). We use the total number of hits to measure user interest in general. When a user subscribes to an OSS project on Freshmeat, he receives emails notifying updates of the

project. We believe that most subscribers are intensive users of the project that they subscribe to. We use the number of subscriptions to measure the interest of intensive users.

METHODS AND RESULTS

LOGISTIC REGRESSIONS: DETERMINANTS OF SURVIVAL

We define an active project as having at least one new announcement since 2004/10/07. Among the sample of 22,992 projects, only 7,231 projects remain active as of 2009/08/17. The rest 15,761 projects did not have any updates after 2004/10/07, although they are still listed on Freshmeat. We run logistic regressions to understand the determinants of survival of OSS projects.

Table 3. Regression of Survival against Topic and License Type
(*significant at the 1% level, **significant at the 5% level, ***significant at the 10% level)

	Regressio1		Regressio2		Regressio3	
	Coef	Std Error	Coef	Std Error	Coef	Std Error
Intercept	0.57*	(0.07)	-2.25*	(0.21)	-2.26*	(0.21)
Age	-0.0005*	(0.000024)	-0.0015*	(0.00004)	-0.0015*	(0.00004)
Desktop	0.01	(0.06)			-0.18	(0.17)
Development	0.27*	(0.03)			0.05	(0.07)
System Admin	0.19*	(0.07)			-0.01	(0.16)
Internet	0.03	(0.04)			-0.11	(0.08)
Communication	0.09**	(0.04)			-0.07	(0.1)
Strong License	-0.09*	(0.03)	-0.38*	(0.04)	-0.28*	(0.06)
ln(Hits)			0.52*	(0.04)	0.54*	(0.04)
ln(Subs)			0.35*	(0.02)	0.35*	(0.02)
ln(anncmnt)			1.24*	(0.03)	1.24*	(0.03)
Desk*L					-0.03	(0.20)
Dev*L					-0.0002	(0.10)
Sys*L					-0.22	(0.20)
Int*L					-0.22**	(0.10)
Com*L					-0.16	(0.13)

Our dependant variable, survival, is equal to 1 if a project has been active since 2004/10/07 and 0 otherwise. We first run a logistic regression of survival against project age,

five topic dummy variables (Desktop Environment, Software Development, System Administration, Internet, and Communication), and license type. Regression 1 in Table 3 reports the results. The results show that projects on Software Development, System Administration, and Communication have higher probability of surviving, but the coefficient of Communication is small.

We then run a logistic regression of survival against age, license type, developer effort and user interests. Regression 2 in Table 3 reports the results. The results show that OSS survival is positively correlated with general user interest, intensive user interest, and developer effort.

The results of the two regressions show that restrictive license has an adverse impact on OSS survival. However, the restrictive license, GPL, is the most popular license among OSS projects. More than 60% of projects in our sample use GPL license. To further investigate this relationship we run a logistic regression of survival against user interests, developer effort, topic, license, and the interaction terms between topic and license. Regression 3 in Table 3 reports the results. The coefficients of the interaction terms show that restrictive license has an adverse impact only on projects about Internet technology. This finding supports the theory of Lerner and Tirole (2005) that standards are particularly important in Internet technology and unrestrictive license is more helpful in getting software established as a standard.

THE RELATIONSHIPS AMONG DETERMINANTS OF OSS SURVIVAL

Existing literature suggests that several determinants of survival are interrelated with each other (Subramaniam et al., 2009). We run regressions to explore the interrelationships among developer effort, interest of general users, interest of intensive users, and license type.
We first run regressions to see how developer effort is allocated towards different OSS projects. Table 4 lists the regression results. Regression 1 shows that developer effort and user interest (both general and intensive users) in the same period are positively correlated. This suggests that more effort is devoted to relatively popular projects. Regression 2 investigates the impact of user interest in the last period on current developer effort. The results show that the interest of general users (measured by the number of hits) in the past does not have significant impact on later developer effort. In contrast, the interest of intensive users in the past does have significant positive impact on later developer effort. This suggests that the interest of intensive users has a persistent positive impact on developer effort, while the interest of general users only has a short-term positive impact on developer effort.

The regressions in Table 4 include five dummy variables of software topic. The results show that OSS with a topic of Software Development attracts more developer effort than the baseline projects. The results in Table 4 also show that restrictive license (GPL) has a negative impact on developer effort.

Table 4. Regression of Effort against User interest and Topic (*significant at the 1% level, **significant at the 5% level, ***significant at the 10% level)		
Dependent variable	Regression 1 ln($Anncmnt_{t1}$)	Regression 2 ln($Anncmnt_{t1}$)
Intercept	-0.93*	1.03*
	(0.06)	(0.07)
ln($Anncmnt_{t0}$)	0.52*	0.66*
	(0.007)	(0.01)
ln($Hits_{t0}$)	-	-0.01
		(0.02)
ln($Subs_{t0}$)	-	0.09*
		(0.01)
ln($Hits_{t1}$)	0.33*	-
	(0.01)	
ln($Subs_{t1}$)	0.09*	-
	(0.01)	
Strong license	-0.02	-0.07*
	(0.02)	(0.02)
Desk	-0.07	-0.06
	(0.05)	(0.06)
Dev	0.03***	0.04***
	(0.01)	(0.02)
Sys	-0.08***	-0.07
	(0.05)	(0.05)
Int	-0.005	0.01
	(0.02)	(0.03)
Com	0.02	0.01
	(0.03)	(0.03)
Desk*L	0.09	0.08
	(0.06)	(0.07)
Dev*L	-0.02	0.01
	(0.03)	(0.03)
Sys*L	0.09	0.10***
	(0.06)	(0.07)
Int*L	-0.01	0.11
	(0.03)	(0.03)
Com*L	0.06***	0.05
	(0.04)	(0.04)
Adj. R-square	0.75	0.67

Table 5. Regression of User Interest against Effort and Topic (*significant at the 1% level, **significant at the 5% level, ***significant at the 10% level)				
	General User		Intensive User	
Dependent	Regression 1 ln($Hits_{t1}$)	Regression 2 ln($Hits_{t1}$)	Regression 3 ln($Subs_{t1}$)	Regression 4 ln($Subs_{t1}$)
Intercept	2.98*	3.54*	-0.37*	0.99*
	(0.06)	(0.08)	(0.05)	(0.06)
ln($Anncmnt_{t0}$)	-	0.10*	-	0.08*
		(0.01)		(0.01)
ln($Hits_{t0}$)	0.53*	0.56*	-	-0.02
	(0.02)	(0.02)		(0.02)
ln($Subs_{t0}$)	-	0.40*	0.70*	0.88*
		(0.01)	(0.01)	(0.01)
ln($Anncmnt_{t1}$)	0.27*	-	0.08*	-
	(0.01)		(0.01)	
ln($Hits_{t1}$)	-	-	0.23*	-
			(0.01)	
ln($Subs_{t1}$)	0.40*	-	-	-
	(0.01)			
Strong license	-0.09*	-0.12*	-0.01	-0.03***
	(0.02)	(0.02)	(0.02)	(0.01)
Desk	0.07	0.01	-0.19*	-0.13*
	(0.05)	(0.06)	(0.04)	(0.05)
Dev	0.07*	0.1*	-0.002	0.02
	(0.02)	(0.02)	(0.02)	(0.02)
Sys	-0.04	-0.05	0.08**	0.04
	(0.05)	(0.06)	(0.04)	(0.04)
Int	0.02	0.04	-0.001	0.03
	(0.02)	(0.03)	(0.01)	(0.02)
Com	0.02	0.001	-0.09*	-0.05**
	(0.03)	(0.03)	(0.02)	(0.03)
Desk*L	-0.07	-0.001	0.10**	0.1***
	(0.06)	(0.07)	(0.05)	(0.05)
Dev*L	0.04	0.05	0.03	0.04
	(0.06)	(0.04)	(0.02)	(0.03)
Sys*L	0.05	0.1	0.01	0.03
	(0.06)	(0.07)	(0.05)	(0.05)
Int*L	0.03	0.02	-0.01	-0.03
	(0.03)	(0.04)	(0.02)	(0.03)
Com*L	-0.04	-0.01	0.01	0.02
	(0.04)	(0.05)	(0.03)	(0.03)
Adj. R-square	0.66	0.53	0.89	0.87

We next run regressions to see how user interest changes with other characteristics. Regressions 1 and 2 in Table 5 investigate the interest of general users, while regressions 3 and 4 in Table 5 investigate the interest of intensive users. The results show that the interests of both general and intensive users are positively correlated with current and past developer effort. We also find that the interest of intensive users in the past positively affects current interest of general users, but not vice versa.

The regressions in Table 5 include topic dummy variables. The results show that projects on Software Development attract the most general user interest, while projects on System Administration attract the most intensive user interest. The results also show that projects on Desktop Environment attract the least interest from intensive users. However, the intensive users will be more interested in projects on Desktop Environment if they are released under restrictive license. We find again that restrictive license adversely affects user interest in 3 out of 4 regressions.

CONCLUSION

In this paper we try to find the determinants of survival in Open Source Software (OSS). We find that OSS survival is positively correlated with general user interest, intensive user interest, and developer effort. Restrictive license has adverse impacts on developer effort, user interests, and OSS survival probability. OSS projects on Software Development and System Administration have higher probability of surviving. OSS creators can benefit from our findings in choosing the license type that best fits their software topic.

The interest of general users is positively related to developer effort in the short run, but has no impact in the longer term. In contrast, the interest of intensive users is more important in determining developer effort in the long run. Projects on Software Development attract more developer effort and general user interest, while projects on System Administration attract the most intensive user interest. This may suggest that general users are mostly software developers while intensive users are mostly system administrators. Further studies need to be conducted to investigate the roles of different users in OSS.

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