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LETTER FROM THE EDITORS

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COMPARISON STUDY ON NEURAL NETWORK AND ORDINARY LEAST SQUARES MODEL TO STOCKS' PRICES FORECASTING

Luna Christie Tjung, California State University at Fresno
Ojoung Kwon, California State University at Fresno
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ABSTRACT

This study presents a Business Intelligence (BI) approach to forecast daily changes in 37 stocks' prices from eight industries. The purpose of our paper is to compare the performances of the Ordinary Least Squares (OLS) model and the Neural Network (NN) model to see which one does a better job of predicting changes in stock prices and to identify critical predictors in forecasting stock prices in order to increase forecasting accuracy for professionals in the market. The BI approach uses a financial data mining technique to assess the feasibility of financial forecasting compared to a regression model using an ordinary least squares estimation method. We used eight indicators such as macroeconomic indicators, microeconomic indicators, market indicators, market sentiments, institutional investors, political indicators, business cycles, and calendar anomalies with a total of 267 independent variables to predict changes in stocks' prices.

Keywords: Business Intelligence, Financial Forecasting, Investment Strategies, Behavioral Finance, Momemtum and Reversal, Overreaction and Underreaction, Technical Analysis, Data Mining, Forecasting Techniques, and Neural Networks

INTRODUCTION

Business Intelligence, such as data mining applications, has made some significant contribution to forecasting science. Burstein and Holsapple (2008) state that "business intelligence (BI) is a data-driven decision support system that combines data gathering, data storage, and knowledge management with analysis to provide input to the business decision process." According to Han and Kamber (2006), "data mining is extracting knowledge from large amounts of data".

Neural Network is one of these data mining applications and useful in making complex predictions in many disciplines. There are many examples of successful data mining being applied. DuMouchel (1999) used Bayesian data mining to work with large frequency tables with millions of cells for FDA Spontaneous application. Giudici (2001) used Bayesian data mining for benchmarking and credit scoring in highly dimensional complex datasets. Jeong, et.al. (2008) integrated data mining with a process designed using the robust Bayesian approach. “Mostafa (2010) reported many other applications such as air pollution forecasting (e.g. Videnova, Nedialkova, Dimitrova, & Popova, 2006), maritime traffic forecasting (Mostafa, 2004), airline passenger traffic forecasting (Nam & Yi, 1997), railway traffic forecasting (Zhuo, Li-Min, Yong, & Yan-hui, 2007), commodity prices (Kohzadi, Boyd, Kemlanshahi, & Kaastra, 1996), ozone level (Ruiz-Suarez, Mayora-Ibarra, Torres-Jimenez & Ruiz-Suarez, 1995), student grade point averages (Gorr, Nagin & Szczypula, 1994), forecasting macroeconomic data (Aminian, Suarez, Aminian & Walz, 2006), financial time series forecasting (Yu, Wang & Lai, 2009), advertising (Poh, Yao & Jasic, 1998), and market trends (Aiken & Bsat, 1999).”

Mostafa (2010) also shows many literatures in financial forecasting applications of NNs to predict indexes. Started with Cao, Leggio, and Schniederjans (2005) who used NNs to predict stock price movements for firms traded on the Shanghai stock exchange and found that NN models outperform the linear models. Kryzanowski, Galler, and Wright (1993) used NN models with historic accounting and macroeconomic data to identify stocks that will outperform the market. McGrath (2002) used market to book and price earnings ratios in a NN model to rank stocks based on the likelihood estimates. Ferson and Harvey (1993) and Kimoto, Asakawa, Yoda, and Takeoka (1990) used a series of macroeconomic variables to capture predictable variation in stock price returns. McNelis (1996) used the Chilean stock market to predict returns in the Brazilian markets. Yumlu, Gurgen, and Okay (2005) used various NN architectures to model the performance of Istanbul stock exchange over the period 1990–2002. Leigh, Hightower, and Modani (2005) used NN models and linear regression models to model the New York Stock Exchange Composite Index data for the period from 1981 to 1999. Results were robust and informative as to the role of trading volume in the stock market.

From this literature survey we find that no previous studies have attempted to predict the changes in stock prices from various industries with comprehensive independent variables. In this study, we want to focus on the 37 stock prices’ changes from eight industries by incorporating critical independent variables.

If the market is efficient, according to the efficient market hypothesis by Fama, then we cannot predict stocks’ prices. Fama (1970, p. 383) defined efficient market hypothesis (EMH) as the idea where “a market in which prices provide accurate signals for resource allocation, that is, a market in which firms can make production-investment decisions, and investors can choose among the securities that represent ownership of firms’ activities under the assumption that security prices at any time ‘fully reflect’ all available information.” Accordingly, it would be difficult, if not impossible, to consistently predict and outperform the market because the information that one would use to make such predictions would already be reflected in the prices.

Although EMH has become the mainstream in finance and received theoretical and empirical support, the technical analysis has been widely applied on Wall Street for over a century. It has been vigorously challenged by behavioral finance since the 1980s. It is impossible to review all relevant and significant studies to point out the flaws of EMH. Here we will summarize some of the prominent studies that are representative of the recent development.

EMH is based on three key fundamental assumptions. One of them is that market participants are perfectly rational and can value securities rationally all the time. Next, if there are irrational investors, their trading activities will cancel out with one another or will be arbitraged away by other rational investors (Shleifer, 2000). Finally, investors have well-defined subjective utility functions to be maximized. As Herbert Simon (1982 and 1997), a Nobel laureate, pointed out, when there is risk and uncertainty or incomplete information about an alternative or high degree of complexity such as investing, people tend to behave somewhat differently from rationality. This is what Simon called bounded rationality. Bounded rationality "is used to designate rational choice that takes into account of the cognitive limitations of the decision-maker, limitations of both knowledge and computational capacity. Bounded rationality is the central theme in the behavioral approach to economics, which is deeply concerned with the ways in which the actual decision-making process influences the decisions that are reached". (Simon, 1997, p. 291) In other words, the underlying assumptions of EMH can exist only in Plato's idealistic world. It may be an elegant theory, but it cannot exist in the complex, uncertain, and risky investing environments and financial markets.

In fact, Simon (1955, 1982), Kahneman, Slovic, and Tversky (1984), and Kahneman and Tversky (1979) brought the psychological aspects of decision-making into economics and finance and built the foundation for so-called behavioral economics and finance. However, behavioral finance caught the attention of the finance profession and investment community since the empirical studies of De Bondt and Thaler (1985, 1987) were published. Their 1985 paper was based on the monthly return data of the New York Stock Exchange common stocks from January 1926 to December 1982, while their 1987 follow-up study used the Annual Industrial COMPUSTAT tapes data from 1965 to 1984. They discovered that investors tended to overweigh recent information and underweigh base rate information and also found that portfolios of prior losers outperformed that of prior winners. If investors count on the representativeness heuristic, a tendency to make decisions or judge information that fits their preconceived categories or stereotypes of a situation, they become too optimistic about the recent winners and too pessimistic about the recent losers. In recent years, behavioral finance has become more widely accepted as a result of further works such as Shefrin (2000), Shiller (2000, 2002, and 2003), Hirshleifer (2000), and Thaler (2005).

People in general and investors in particular tend to predict future uncertain conditions by focusing on recent history but pay little attention to the possibility that the short recent history may occur by chance as found by Kahneman and Turversky (1979) in which market participants systematically violate Bayes rule and other maxims of probability theory to predict the risky and uncertain outcomes. People incline to weigh heavily on some memorable, salient, and vivid evidence than the true relevant information. Based on their prospect theory, they find that investors are reluctant to sell losing stocks. Similarly, by using a very large sample of individual investors at a large discount broker Barber and Odean (2000) also find that overconfident investors tended to sell winners too soon and keep losers too long. Kahneman and Riepe (1998) found that investors pervasively and systematically deviated from the maxims of economic rationality by overweighing the recent information and underweighing the base line information. Furthermore, Odean (1998, 1999) find that investors are inclined to overestimate their own abilities and be too optimistic about future conditions, focus too much on attention-getting information that is consistent with their existing beliefs, and emphasize their private information too heavily. He also found that people tend to demonstrate the highest overconfidence when dealing with complex and difficult matters, such as investing in stocks and predicting their future returns. He also found that overconfident traders are likely to trade too much and too frequently, lower their expected utility, generate greater market depth, and increase market volatility. Daniel, Hirshleifer, and Subrahmanyan (1998) argue that due to investors' self-attribution bias and representative heuristic their confidence grows significantly when public information agrees with investors' private information. However when public information disagrees with investors' private information, their confidence declines only slightly. As a result, investors tend to overreact to private information signals and underreact to public information signals. They also show that positive return autocorrelation is resulting from continuous short-term overreaction followed by long-term correction. These findings of short-term continuation and long-term reversal are consistent with a study by Balvers, Wu, and Gilliand (2000) when they used the national stock index data of 18 countries from 1969 to 1996. Finally, Easterwood and Nutt (1999) found that even professional analysts underreact to most negative information but overreact to most positive information.

The ways experts theorizing investors' overconfidence are quite different. Daniel, Hirshleifer, and Subramanyan (1998) attribute overconfidence to investors' self-attribution of investment outcomes and the resulting short-term returns continuation and long-term reversal. They show that positive return autocorrelations are the result of continuing overreaction only to be followed by long-term negative return autocorrelations. In addition, biased self-attribution increases positive short-term positive autocorrelations or momentum. Based on bounded rationality of market participants, Hong and Stein (1999) divided investors into news-watchers and momentum traders. They assumed that "each news-watcher observes some private information, but fails to extract other news-watchers information from prices. If information diffuses gradually across the population, prices underreact in the short run. The underreaction means that the momentum traders can profit by trend-chasing. However, if they can only implement simple (i.e., univariate) strategies, their attempts at arbitrage must inevitably lead to overreaction at long horizons." (Hong and Stein, p.2143) In their model, the news-watchers made forecasts on the basis of private observations about future fundamentals without taking into account the current and past prices. The momentum traders, on the other hand, applied only simple or univariate functions of the past prices to make their forecasts. Both theories lead to similar conclusions of short-term momentum and long-term reversal of returns. If indeed these are the general patterns of market movement, the investors can easily follow the patterns and profit from them. Many technical analysts have incorporated momentum and trading volumes to identify some patterns for profitable opportunities.

Recently, Gutierrez and Kelley (2008) used weekly data based on the midpoint of the final bid and ask quotes from Wednesday to Wednesday for the period of 1983-2003. They included all stocks listed on the NYSE and AMEX but excluded stocks of $5 or lower. They formed a portfolio of winners as those stocks with returns in the highest decile and portfolio of losers as those stocks with returns in the lowest decile. The differential profits between the winners' portfolio and losers' portfolio demonstrated significant reversal or negative returns in the first two weeks. The profit differentials became positive and significant from week 4 to week 52. Their findings were consistent with the 3 to 12 months continuation of return momentum found by Jegadeesh and Titman (1993). They used calendar data rather than event data typically used in most other studies. In other words, their findings of very short-term one to two week reversal and up to one year long-term momentum or underreaction were quite different from the news or information-driven overreaction and underreaction found by Daniel, Hirshleifer, and Subramanyan (DHS) (1998) or Hong and Stein (HS) (1999). In a DHS study, investors overreacted to private information and underreacted to public information while in a HS study news-watchers underreacted to public news and the trend chasers overreacted to price movements. They also found that week-1 stock return reversal is statistically greater for large stocks, for more institutional owned stocks, for greater volatility stocks, and for more analyst-covered stocks. The practical implication from this empirical study is that investors should buy the top winners and short the large losers in the previous week and realize the extra profits over the next 52 weeks.

Based on the Merged COMPUSTA-CRSP data base for the period of July 1963-June 2005, Menzly and Ozbas (2010) hypothesized that since investors specialize in certain market segmented industries, valuable and relevant information tends to diffuse gradually throughout the entire financial markets. First, they found that returns of individual stocks and industries demonstrate strong cross-predictability with some lagged returns in supplier and customer industries. Second, the results showed that the smaller the number of analysts or institutional ownership, the greater the cross-predictability. More analyst coverage or institutional ownership increased the speed of information diffusion and reduced the cross-predictability. Analysts and institutional investors may be considered as informed investors. Finally, they found that when investors buy stocks with high returns in supplier industries over the previous month and at the same time sell stocks with low returns in supplier industries over the previous month, will generate annual excess returns of 7.3%. If investors apply a similar strategy to buy and sell the stocks of the customer industries in the previous month, the annual excess returns will be 7.0%. When they incorporate the three factors identified by Fama and French (1994), both trading strategies are still consistently profitable with no significant effects by the three factors.

Based on the findings from these empirical studies on overreaction/underreaction, short-term (one week or one month) reversal, medium-term (three week or three months to 52 weeks or one year) continuation or momentum, and long-term (three to five years) reversal, and the most recent findings on cross-predictability, it appears that stock prices or returns may be predictable and excess returns may be realized with proper trading strategies. These findings in a sense support the traditional technical analysis and some arguments advanced by behavioral finance. We now turn to illustrate some examples to see how academicians tested the efficacy of technical analyses.

Brock, Lakonishok, and LeBaron (BLL) (1992) applied two simple trading rules: the moving averages and trading range break-out (TRB). The data they used were the daily Dow Jones Industrial Average (DJIA) from the first trading day in 1897 to the last trading day in 1986. In addition to the full sample they also tested the nonoverlapping subsamples: 1/1/1897-7/30/1914, 1/1/1915- 12/31/1938, 1/1/1939-6/30/1962, and 7/1/1962-12/31/1986. The variable-length moving average (VMA) or fixed-length moving average (FMA) was used to initiate some buy (sell) signals when the short moving average crosses the long moving average from below (above) with or without a band such as plus or minus one percent. They tried some popular short- and long moving average combinations of 1-50, 1-150, 5-150, 1-200, and 2-200. In TRB trading rule, a buy signal occurs when the price penetrates the resistance level or the local maximum. Similarly, when the price penetrates the support level or local minimum, a sell signal will result. To be comparable to the moving average rules the maximum or minimum prices were based on the past 50, 150, or 200 days. To avoid the possible dependencies across different trading rules, leptokurtosis, autocorrelation, conditional heteroskedasticity, and changing conditional means, they applied the bootstrap methodology to test and validate their empirical findings. Their empirical results strongly supported the technical trading strategies with returns from buy signals being 0.8 percent higher than the returns from sell signals over 10-day period. The returns from buy (sell) signals were higher (lower) than the normal returns. They pointed out that the return difference between buys and sells cannot be explained by risk differential.

In addition to moving averages, support and resistance levels, and channel breakouts, Sullivan, Timmermann, and White (1999) considered the on-balance volume (OBV) indicator. The OBV indicator "is calculated by keeping a running total of the indicator each day and adding the entire amount of daily volume when the closing price increases, and subtracting the daily volume when the closing price decreases." The OBV trading rules are similar to the moving average trading rules except the use of OBV indicator rather than price. They applied the DJIA daily data from 1897 to 1996 extending 10 more years from BLL study. They found that the BLL results are robust to data-snooping and that technical trading rules are profitable. But they also found that BLL's profitable technical trading rules do not repeat in the out-of-sample experiment for the period of 1987-1996. In fact, the results were reversed.

Recently, Lo, Mamaysky, and Wang (LMW) (2000) provided precise definitions of head-and shoulders having three peaks with the middle peak higher than the other two, broadening tops and bottoms, triangle tops and bottoms, and rectangle tops and bottoms. The last three definitions are characterized by five consecutive extrema. They also specify the double tops and double bottoms (LMW, pp.1716-1718). Then they applied the nonparametric kernel regression method to identify the nonlinear patterns of stock price movements. Using CRSP data they applied the goodness-of-fit and Komogonov-Smirnov tests to the daily returns of individual NYSE/Amex and Nasdaq stocks from 1962 to 1996. They found that some patterns of technical analysis provided incremental information and had practical value. They contended that technical analysis may be improved by their automated algorithms to determine some optimal patterns. Finally, Blume, Easley, and O'Hara (BEO) (1994) developed a theoretical model that showed a "technical analysis is valuable because current market statistics may be sufficient to reveal some information, but not all. Because the underlying uncertainty in the economy is not resolved in one period, sequences of market statistics can provide information that is not impounded in a single market price."(BEO, p.177) In their model, volume can provide some information different from that provided by price.

In brief, trading patterns of price and volume as used by technical analysts over a century indeed provide certain valuable and/or profitable information. It is widely known that most technical analysts apply both technical analyses and fundamental analyses to manage their portfolios and conduct their trading. Technical patterns and market momentum and reversal are helpful to market participants to develop some forecasting methods and models to predict stock prices. In this study, we tried to identify various factors to forecast prices of some randomly selected stocks and funds from different industries. Since ordinary least squares (OLS) has been widely applied, we used it in this study. In addition, a neural network (NN) was applied for comparison.

For the remainder of the paper, we introduced a business intelligence (BI) technique, specifically Neural Network, and discussed how NN can be used to predict stock prices. In the next section, we compared and contrasted Ordinary Least Squares (OLS) and Neural Network (NN) models with regard to their accuracy and ease of use in stock forecasting. Next, we explained the methodology for testing our hypothesis including details on our predictors and data normalization. Finally, we presented the results and discussed the implications of our findings.

TOOLS AND TECHNIQUES OF STOCK FORECASTING

The Ordinary Least Squares (OLS) model has many advantages. It is easy to use, to validate, and typically generates the best combination of predictors by using stepwise regression. However, OLS is a linear model that has a relatively high forecasting error when forecasting a nonlinear environment, which is common in the stock markets. Also, the OLS model can only predict one dependent variable at a time. On the other hand, a neural network model has high precision, is capable of prediction in nonlinear settings, and addresses problems with a great deal of complexity. Given these advantages, we expected the neural network to outperform OLS in predicting stock prices.

In addition to determining which factors best predict changes in stock prices, we also compared the two analytical strategies of OLS and artificial neural networks. Hammad, Ali, and Hall (2009) showed that the artificial neural network (ANN) technique provides fast convergence, high precision and strong forecasting ability of real stock prices. Traditional methods for stock price forecasting are based on statistical methods, intuition, or on experts' judgment. Traditional methods' performance depends on the stability of the prices; as more political, economical and psychological impact-factors get into the picture, the problem becomes nonlinear, and traditional methods need a more nonlinear method like ANN, fuzzy logic, or genetic algorithms.

Along the same lines as Hammad et al., (2009), West, Brockett, and Golden (1997) concluded that the neural network offers superior predictive capabilities over traditional statistical methods in predicting consumer choice in nonlinear and linear settings. Neural networks can capture nonlinear relationships associated with the use of non-compensatory decision rules. The study revealed that neural networks have great potential for improving model predictions in nonlinear decision contexts without sacrificing performance in linear decision contexts.

However, neural networks are not a panacea. For example, Yoon and Swales (1991) concluded that despite neural network's capability of addressing problems with a great deal of complexity, as the increase in the number of hidden units in neural network resulted in higher performance up to a certain point, additional hidden units beyond the point impaired the model's performance.

Prior research and common wisdom have suggested several factors that might be used in OLS or a neural network model to predict stock prices. Grudnitski and Osburn (1993) used general economic conditions and traders' expectations about what will happen in the market for their futures. Kahn (2006) stated that the sentiment indicator is the summation of all market expectation that is driven by volatility index, put/call ratio, short interest, commercial activity, surveys, magazines, emotions, and many more. Tokic (2005) showed that political events like the war on terror, fiscal policy to lower taxes, and monetary policy to lower short-term interest, and the increase in the budget deficit are related to stock prices. Nofsinger and Sias (1999) showed that there is a strong positive relation between annual changes in institutional ownership and returns over the herding interval across different capitalizations.

Moshiri and Cameron (2000) compared the most commonly used type of artificial neural network (the back-propagation networks (BPN) model) with six traditional econometric models (three structural models and three time series models) in forecasting inflation. BPN models are static or feed-forward-only (input vectors are fed through to output vectors, with no feedback to input vectors again); they are hetero-associative (the output vector may contain variables different from the input vector) and their learning is supervised (an input vector and a target output vector both are defined and the networks tend to learn the relationship between them through a specified learning rule). The three structural models include (1) the reduced-form inflation equation that follows from a fairly standard aggregate demand-aggregate supply model with adaptive expectations, (2) the inflation equation from Ray Fair's econometric forecasting model, and (3) a monetary model for forecasting inflation. The three time series models are (1) an ARIMA (Autoregressive integrated moving average) model, the single-variable model derived from Box-Jenkins methodology, (2) a Vector Autoregression or VAR model, considered the joint behavior of several variables, and (3) a Bayesian Vector Autoregression or BVAR model, the combination of VAR model with prior information on the coefficients of the model and estimated using a mixed-estimation method. In one-period-ahead dynamic forecasting, the information contained in the econometric models was contained in the BPN, and the BPN contained further information; the BPN models were superior in all four comparisons. Over a three-period forecast horizon the BPN models were superior in two comparisons (VAR and Structural) and inferior in two (ARIMA and BVAR). Over a twelve-period forecast horizon, the BPN models were superior in two comparisons (VAR and Structural) and equally good in two (ARIMA and BVAR). Moshiri (2001) concluded that the BPN model has been able to outperform econometric models over longer forecast horizons.

There are many examples of the successful applications of data mining. DuMouchel (1999) used Bayesian data mining to work with large frequency tables with millions of cells for FDA Spontaneous application. Giudici (2001) used Bayesian data mining for benchmarking and credit scoring in highly dimensional complex datasets. Jeong, et.al. (2008) integrated data mining to a process designed using the robust Bayesian approach. Dutta, Jha, Laha, and Mohan (2060) applied artificial neural network (ANN) models to forecast Bombay Stock Exchange's SENSEX weekly closing values. They compared two ANNs they developed and trained using 250 weeks' data from January 1997 to December 2001. They used root-mean square error and mean absolute error to evaluate forecasting performance of the two ANNs for the period of January 2002-December 2003. Ying, Kuo, and Seow (2005) applied the hierarchical Bayesian (HB) approach to stock prices of 28 companies contained in DJIA from the third quarter of 1984 to the first quarter of 1998. They found the HB method predicted better than the classical method. Finally, Tsai and Wang (2009) applied ANN and decision tree model (DT) and found that the combination of ANN and DT models resulted in more accurate prediction.

HYPOTHESIS

Because the neural network (NN) model can address problems with a great deal of complexity and improve its prediction in nonlinear settings, we expect that the neural network will outperform OLS in predicting stock prices.

H_0 *OLS model better predicts stock prices than NN Model*

H_1 *NN model better predicts stock prices than OLS Model*

METHODOLOGY

In order to forecast the changes in stock prices, we used the daily changes in stock prices of 37 stocks from September 1, 1998 to April 30, 2008. This 10-year time period was selected because we wanted to include the dot com bubble and the early part of the recent global financial crisis into our forecasting horizon instead of including expansion periods only. In our previous study, we used only seven financial stocks because they were relatively volatile and more sensitive to economic news. In this study, we would like to expand and include 37 stocks in various industries as shown in the Table 2 to examine whether we can generalize our findings from our previous study. In that study, we found that NN provided superior performance with up to 96% forecasting accuracy compared to OLS model with only 68%. (Tjung, Kwon, Tseng, and Bradley-Geist, 2010)

Predictors (see Appendix for full details)

As shown in the Appendix, we used eight indicators such as macroeconomic leading indicators (global market indices), microeconomic indicators (competitors), political indicators (presidential election date and party), market indicators (USA index), institutional investors (BEN), and calendar anomalies as our independent variables to predict changes in daily financial stock prices. We also took into account the business cycle factors such as the "dot-com bubble" into our forecasting horizon with dummy variables. We gathered our data through the National Bureau of Economic Research (NBER), Yahoo Finance, Federal Reserve Bank, Market Vane (MV), NYSE, and FXStreet.

The macroeconomic indicators included the 18 major global stock indices. The microeconomic indicators included the competitors and companies from different industries. There are 213 of them. The daily market indicators included changes in price and volume of the S&P500, Dow Jones Industrial, Dow Jones Utility, and Dow Jones Transportation. The sentiment indicators included the Volatility Index (VIX) and CBOE OEX Implied Volatility (VXO).

The political indicators included major elections and the political party in control. We denoted a non-election date with 0. The calendar anomalies include a daily, weekly, monthly, and pre-holiday calendar. The daily calendar includes Monday, Tuesday, Wednesday, Thursday, and Friday. The weekly calendar includes week one to week five. The monthly calendar includes January to December. We denoted Tuesday, week 2, and September with dummy variable zero in the OLS model. Contrastingly, we included them in the NN model. The business cycle included the recession from technological crash and current bear market with dummy variable one.

Coding

In NN model, we included all qualitative variables (political indicators, calendar anomalies, and business cycle) by using multiple neurons to minimize its bias. Table 1 below shows a NN coding example for political indicators. Coding is necessary to avoid discrimination to qualitative variables. Instead of having 1 column of both 0 and 1 dummy for both Republican and Democratic Party like in the OLS model, coding assigned 2 different neurons or 2 columns of both 0 and 1 for both 0 and 1 dummy. If we have just one column like in the OLS model, 1 for Republican and 0 for Democratic, Democrats will get less value compared to Republicans, thus impairing the network performance.

Table 1: Sample Coding For Political Party Preference

	None	Democratic	Republican	Both
Neuron 1 (Republican)	0	0	1	1
Neuron 2 (Democratic)	0	1	0	1

OLS Models

We used SPSS to perform stepwise regression to create a unique regression model for each company. First, we included all independent variables to predict dependent variables with a 95% of confidence interval. Second, we got statistically significant independent variables with a p-value of <5% and took the coefficients of the statistically significant independent variables to calculate the dependent variable value from 152 randomly selected datasets. Third, we calculated the forecasting error between the predicted and actual values. Then, we measured the mean and standard deviation of the % error = (actual value-predicted value)/actual value.

$$Y = \alpha + \beta_1 X_1 + \beta_2 X_2 + ... + \beta_n X_n \quad \text{where } n = 1 \text{ to } 267 \text{ (the initial model)}$$

NN Model

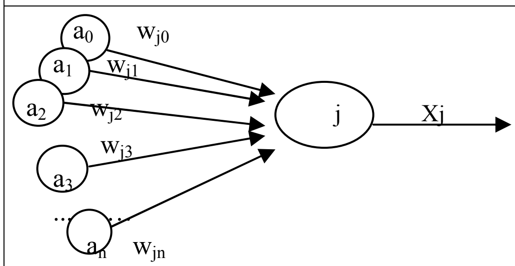
A basic neural network model is shown in Figure 1. Input neurons (1 to n) are connected to an output neuron (j) and each connection has an assigned weight (w_{j0} to w_{jn}). In this example, the output of j becomes 1 (activated) when the sum of the total stimulus (S_j) becomes greater than 0 (zero). The activation function in this example used a simple unit function (0 or 1), but other functions (Gaussian, exponential, sigmoid or hyperbolic functions) are used for complex networks.

Backpropagation is one of the most popular learning algorithms in neural networks and is derived to minimize the error using the following formula:

$$E = 0.5 \sum_{p}(\sum_{k} (t_{pk}-o_{pk})^2)$$

where: p = the pattern i
k = the output unit
t_{pk} = the target value of output unit k for patter p
O_{pk} = the actual output value of output layer unit k for patter p.

Figure 1: Basic Neural Network Model



$$S_j = \sum_{i=0}^{n} a_i w_{ji}$$

where:
w_{ji} = the weight associated with the connection to processing unit j from processing unit i
a_i = the value output by input unit i.
Output of j = X_j $\{$ 0 if $Sj \le 0$ *and* 1 if $Sj > 0$

Source: Dayhoff, J. (1990) Neural Network Architectures, New York: Van Nostrand Reinhold

Genetic Algorithm

Neural networks used a genetic algorithm that has capabilities in pattern recognition, categorization, and association. Turban (1992) showed that a genetic algorithm enabled neural networks to learn and adapt to changes through machine learning for automatically solving complex problems based on a set of repeated instructions. It would be similar to biological processes of evolution. One primary characteristic of general algorithms that we found in Alyuda NeuroIntelligence NN application is its reproduction. Genetic algorithms enable NN to produce improved solutions by selecting input variables with higher fitness ratings. Alyuda NeuroIntelligence enables us to retain the best network.

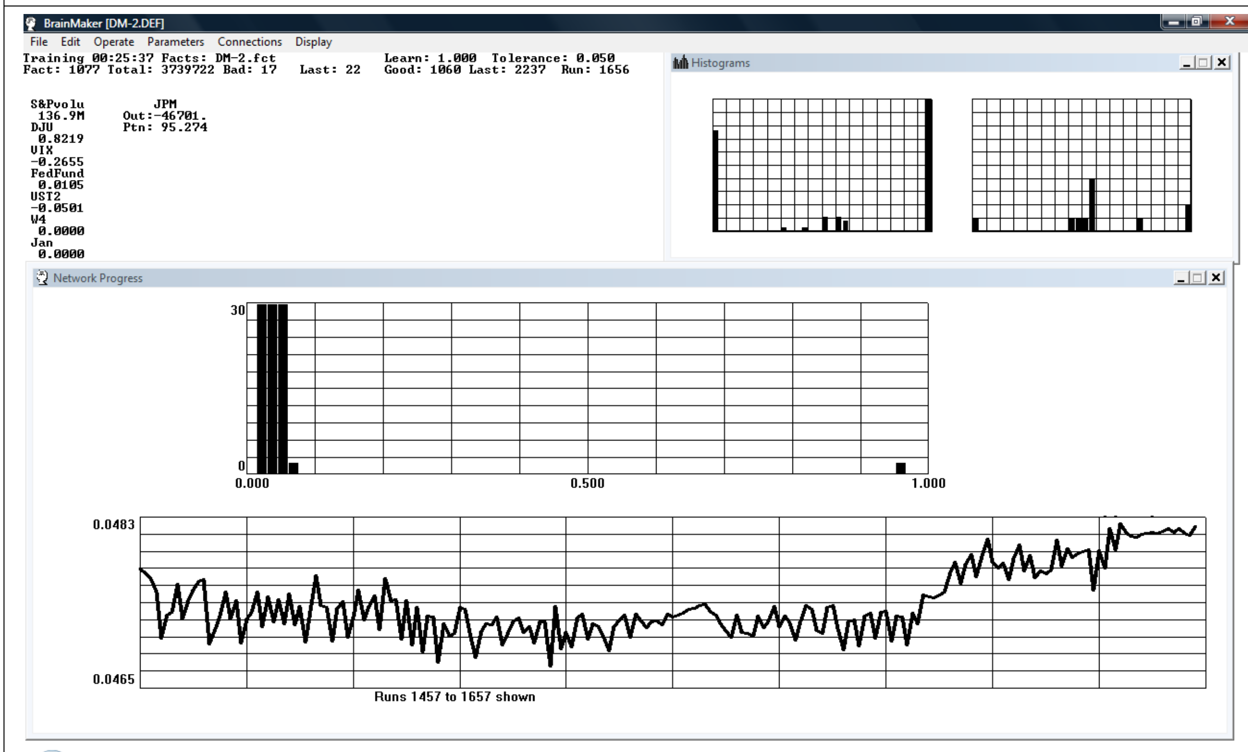
Fuzzy Logic

Fuzzy logic used the process of normal human reasoning to cope with uncertainty or partial information. Turban (1992) showed that fuzzy logic can be advantageous because it provides flexibility for the unexpected, gives options to make an educated guess, frees the imagination by asking "what if..?", and allows for observation.

First Attempt using BrianMaker

First, we used BrainMaker software to create the NN model for four companies (C, GS, JPM, and MS), but BrainMaker had a major limitation of 20 variables, and so it was not adequate for the number of variables in our model. We included independent variables from stepwise regression to BrainMaker due to the limit. However, BrainMaker burst out and unable to learn. BrainMaker failed to perform as shown in Figure 2.

Figure 2: Brainmaker Error Distribution



Second Attempt using NeuroIntelligence

Alyuda NeuroIntelligence allowed us to handle more data and find the best network architecture. So, with this benefit, we increased the number of independent variables from 20 to 267 variables (see Table A.1 to A.8 in Appendix) and the number of dependent variables from 4 to 37 variables (see Table 2). The major difference with the number of independent variables is that they are all sub-industries in the market to increase our performance accuracy. We also took out the market vane indicators of the commodity market because of its lack of correlation with our dependent variables.

We used Alyuda NeuroIntelligence to create the second generation of NN models. We did data manipulation by using the changes or the first difference of our independent variables except for the dummy variables. We also normalized the data because there are negative to positive numbers. We followed a seven-step neural network design process to build up the network. We used the Alyuda NeuroIntelligence to perform data analysis, data preprocessing, network design, training, testing, and query. The dataset was analyzed during data analysis function. As a result, the neural network showed missing values, wrong type values, outliers, rejected records and columns, input columns, and output column in the dataset.

We tried both logistic and hyperbolic tangent function to design the network to see which method had higher accuracy. A hyperbolic tangent is a sigmoid curve and is calculated using the following formula: $F(x)= (e^{x}-e^{-x})/(e^{x}+e^{-x})$ with output range of [0..1]. Logistic function also has a sigmoid curve and is calculated by: $F(x)=1/(1+e^{-x})$ with output range of [-1..1]. Empirically, it is often found that hyperbolic tangent function performs better than the logistic function. However, we wanted to try both functions and select a better one to increase performance. From table below, we found out that logistic functions outperform hyperbolic tangent function 27 out of 37 times. There is no significant spread by using either logistic or hyperbolic tangent function, but we can try both functions to increase performance accuracy.

Table 2: Performance Comparison On Logistic And Hyperbolic Tangent Method

BASIC MATERIALS INDUSTRY	Iterations	Logistic – mean of error (standard deviation)	Hyperbolic Tangent – mean of error (standard deviation)
1 BHP BILLITON [BHP]	1001	**3.86% (4%)**	4.14% (4.09%)
2 EXXON MOBIL [XOM]	781	**2.85% (2.49%)**	4.04% (3.37%)
3 TRANSOCEAN [RIG]	1001	**4.57% (5.05%)**	5.03% (5.78%)
4 SCHLUMBERGER [SLB]	1001	6.64% (8.21%)	**5.54% (6.44%)**
5 IMPERIAL OIL [IMO]	901	4% (5.12%)	**3.92% (5.10%)**
6 BARRICK GOLD CORP. [ABX]	1001	**4.31% (3.55%)**	5.17% (3.74%)
CONGLOMERATES			
7 GENERAL ELECTRIC CO. [GE]	1001	9.50% (9.69%)	**7.44% (7.18%)**

Table 2: Performance Comparison On Logistic And Hyperbolic Tangent Method			
BASIC MATERIALS INDUSTRY	Iterations	Logistic – mean of error (standard deviation)	Hyperbolic Tangent – mean of error (standard deviation)
CONSUMER GOODS			
8 PACCAR INC. [PCAR]	1001	**3.73% (3.8%)**	3.96% (4.41%)
9 JOHNSON CONTROLS INC. [JCI]		**6.14% (6.87%)**	6.34% (6.80%)
10 PROCTER & GAMBLE CO. [PG]	1001	**5.90% (5.21%)**	5.91% (5.38%)
FINANCIAL INDUSTRY			
11 T. ROWE PRICE GROUP INC. [TROW]	746	**3.29% (4.48%)**	3.67% (4.39%)
12 JPMORGAN CHASE & CO. [JPM]	1001	**3.79% (3.48%)**	3.99% (3.91%)
13 MORGAN STANLEY [MS]	1001	**4.86% (5.37%)**	5.53% (5.69%)
14 CHARLES SCHWAB [SCHW]	1001	**3% (4.27%)**	3.56% (4.84%)
15 PLUM CREEK TIMBER CO. INC. [PCL]	1001	**2.10% (2.28%)**	2.43% (2.25%)
16 HCP INC. [HCP]	356	**2.33% (2.11%)**	2.42% (2.18%)
17 HOST HOTELS & RESORTS INC. [HST]	604	**3.41% (3.53%)**	3.54% (3.56%)
18 PUBLIC STORAGE [PSA]	1001	**2.78% (3.13%)**	3.15% (3.57%)
19 BOSTON PROPERTIES INC. [BXP]	1001	**2.25% (2.61%)**	2.54% (3.04%)
20 SIMON PROPERTY GROUP INC. [SPG]	776	**3.19% (3.05%)**	3.42% (3.29%)
HEALTHCARE			
21 JOHNSON & JOHNSON [JNJ]	591	**6.26% (5.92%)**	7.92% (6.12%)
22 AMGEN INC. [AMGN]	626	**7.58% (6.78%)**	9.30% (8.04%)
INDUSTRIAL GOODS			
23 CATERPILLAR INC. [CT]	691	6.28% (7.05%)	**5.48% (6.6%)**

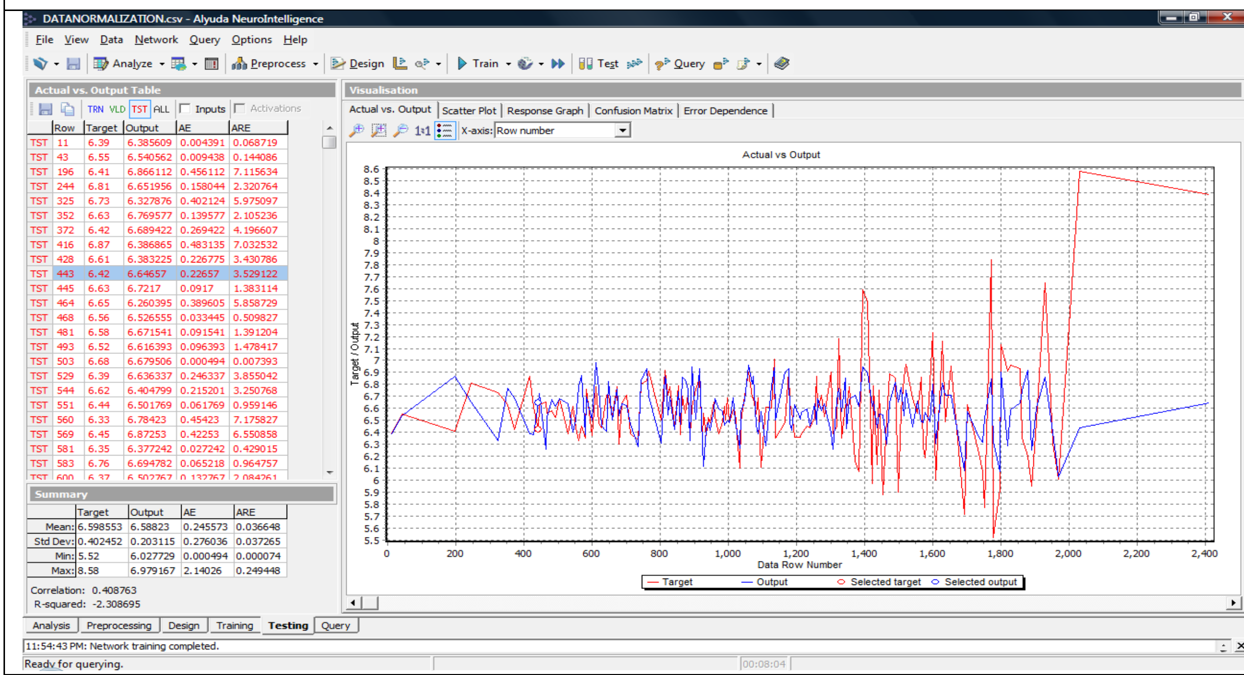
Table 2: Performance Comparison On Logistic And Hyperbolic Tangent Method			
BASIC MATERIALS INDUSTRY	Iterations	Logistic – mean of error (standard deviation)	Hyperbolic Tangent – mean of error (standard deviation)
24 VULCAN MATERIALS CO. [VMC]	1001	**4.47% (4.60%)**	4.56% (5.04%)
25 EMCOR GROUP INC. [EME]	1001	**6.06% (6.41%)**	6.27% (6.94%)
26 MCDERMOTT INTERNATIONAL INC. [MDR]	1001	2.84% (3.84%)	**2.81% (3.90%)**
27 EMERSON ELECTRIC CO. [EMR]	1001	**11.30% (10.94%)**	12.16% (12.38%)
28 PRECISION CASTPARTS CORP. [PCP]	1001	**2.67% (2.28%)**	2.71% (2.38%)
SERVICES			
29 FEDEX CORPORATION [FDX]	1001	12.93% (13.01%)	**12.31% (12.28%)**
30 GENUINE PARTS CO. [GPC]	1001	5.86% (5.05%)	**5.78% (5.21%)**
31 THE HOME DEPOT INC. [HD]	1001	**10.54% (14.92%)**	10.84% (15.84%)
32 W.W. GRAINGER INC. [GWW]	1001	**7.19% (6.70%)**	7.35% (7.28%)
33 TIFFANY & CO. [TIF]	1001	7.51% (7.26%)	**6.34% (6.18%)**
34 BURLINGTON NORTHERN SANTA FE CORP. [BNI]	1001	9.43% (9.63%)	**7.50% (8.19%)**
35 JB HUNT TRANSPORT SERVICES INC. [JBHT]	1001	**6.53% (6.78%)**	6.92% (6.56%)
UTILITIES			
36 SOUTHERN COMPANY [SO]	1001	4.60% (3.56%)	**4.55% (3.46%)**
37 TRANSCANADA CORP. [TRP]	1001	**3.15% (2.93%)**	3.17% (2.96%)

We used Batch Back Propagation model with stopping training condition of 1001 iterations to find the best network during the network training. However, we retrained the network at smaller iterations where the best network at. For all networks, we used the same model architecture of 272-41-1 with different number of iterations. The network architecture consisted of 272 input neurons (additional 5 neurons from coding), 41 neurons in the hidden layer, and one output neuron. The number of iterations is important to escape a local minima and reach a global minima which is the lowest errors possible to train the network.

“Back propagation algorithm is the most popular algorithm for training of multi-layer perceptrons and is often used by researchers and practitioners. The main drawbacks of back propagation are: slow convergence, need to tune up the learning rate and momentum parameters, and high probability of getting caught in local minima.” (Alyuda NeuroIntelligence Manual, 2010)

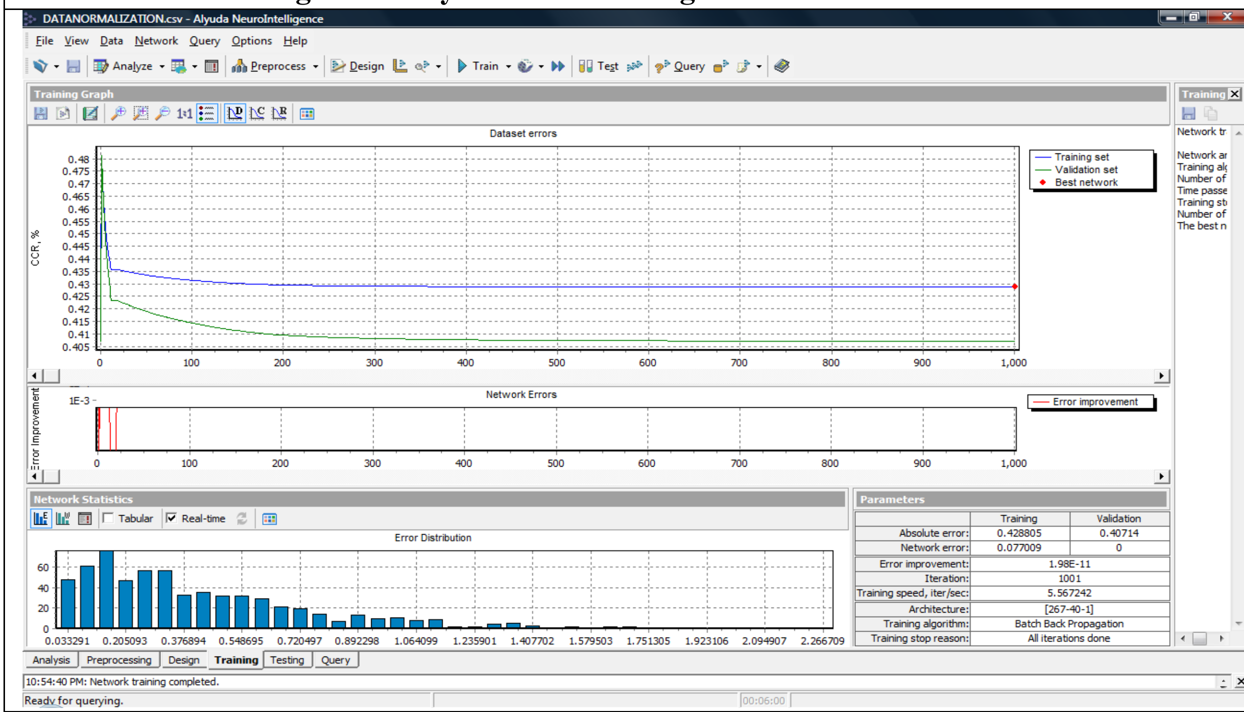
Figure 3: Bhp - Batch Back Propagation: Testing

Model Architecture: 272-41-1 No. of Iterations: 1001



Also, we used overtraining control techniques such as “Retrain” and “Restore” the best network and “Add 10% jitter to inputs,” “Weights randomization method such as Gaussian distribution of network inputs,” and “Retrain network two times of the lowest training error to train the network.” By retaining and restoring the best network, we can prevent over-training such as memorizing data instead of generalizing and encoding data relationships and thus reduce the network error. As a result, validation errors rise while training errors may still decline in the training graph. By adding jitter, we not only can prevent overtraining but also allow the network to escape local minima during training (a major drawback from the batch-back propagation) by adding 10% random noise to each input variable during training. By randomizing the weights, we avoid sigmoid saturation problems that cause slow training. We used a Gaussian distribution because it is characterized by a continuous, symmetrical, bell-shaped curve. A sample screen shot from NeuroIntelligence is shown in Figure 3. Figure 4 shows the error distribution while training. It is reduced rapidly and arrived to the best network at 1001 iterations.

Figure 4: Alyuda Neurointelligence Error Distribution



Data - Model Building Data Set and Performance Testing Data Set for OLS

We used 2431 data points for each company to build the OLS model by running stepwise regression. With stepwise regression, we can reduce our independent variables to only the statistically significant variables. By doing that, we reduced our independent variables range to between 31 and 61 variables. After having the OLS model, we tested the model by using randomly selected 152 data points by calculating the predicting error. Finally, we tested the forecasting accuracy of the OLS with NN methods by calculating the mean and standard deviation of the % error that is error divided by the actual value of the stock price.

Data – Training Data Set, Validation Data Set, and Testing Data Set

Unlike the OLS model, NN model used all independent variables. There are three sets of data used in the neural network model such as training set, validation set, and testing set. The training set is used to train the neural network and adjust network weights. The validation set is used to tune network parameters other than weights, to calculate generalization loss, and retain the best network. The testing set is used to test how well the neural network performs on new data after the network is trained. We used training and validation data to train the network and come up with a model. Finally, we used testing data to test the forecasting errors between the actual and predicted values. Out of 2431 data for each company, we have 152 randomly chosen testing data. The remaining is equally distributed among the training and validation data.

Data Normalization

We looked at the numbers in our data: both positive and negative numbers. We thought we would want to have all positive numbers to see how the neural network learns. So, we wanted to shift up or normalize the data. First, we searched for the lowest negative numbers. We wanted to add the negative numbers to all numbers to make all positive numbers. Second, we took the absolute value of the lowest negative numbers. If it was not done so, we would have negative numbers, plus negative numbers result in bigger negative numbers. For example -6 + (-6) = -12. Third, we wanted to take into account the rounding error by adding 0.1 to the absolute value of the lowest negative numbers. For example, to normalize the data of company A, we added the absolute value of lowest negative numbers of company A that is |-6.7| to 0.1. As a result, we have 6.8. Then we used 6.8 to add all number. Let's say we used the lowest numbers: 6.8 + (-6.7) = 0.1. To sum up, the formula we used to normalize the data = (|lowest negative number| +0.1+ all number in our data set). After we normalized the data, we had both a lower mean and standard deviation for both the NN model and OLS model.

Analysis and Results

We measured our success by testing the accuracy between the NN with OLS model in terms of the significant % forecasting error of the mean and standard error. After analyzing the results, our mean for NN was low (2.47% to 19.68%) but our standard deviation was too high (218.73% to 584.26%). The same happened to the OLS model with a mean of 7.29% to 167.43% and standard deviation of 160.33% to 962.01%. Then, we realized that our % error had both positive and negative numbers because we were using the difference for all our variables except dummy variables. So, we took the absolute value of the error percentage of all variables. Even after we took the absolute value of the error percentage, our mean (127% to 206%) and standard deviation (174% to 532.8%) for NN model were still too high. For the OLS model, we got a mean of 104%-381% and standard deviation of 127% to 849%.

Table 3 shows the means and standard deviations of NN models and OLS models after we normalized the data as mentioned in the Data Normalization section. We have both lower means (2.1% to 12.31%) and standard deviations (2.11% to 14.92%) for NN model. We have similar results for the OLS model with the means (1.93% to 24.8%) and standard deviations (2.15% to 12.3%).

Table 3: Mean And Standard Deviation Of The % Forecasting Error				
BASIC MATERIALS INDUSTRY	COMPANIES	NN Mean (Stdev)	OLS Mean (Stdev)	Average Mean (Stdev)
1 Industrial Metals & Minerals	BHP BILLITON [BHP]	3.86% (4%)	3.93% (3.83%)	3.89% (3.92%)
2 Major Integrated Oil & Gas	EXXON MOBIL [XOM]	2.85% (2.49%)	9.52% (3.92%)	6.18% (3.20%)
3 Oil & Gas Drilling & Exploration	TRANSOCEAN [RIG]	4.57% (5.05%)	7.98% (3.82%)	6.27% (4.44%)
4 Oil & Gas Equipment & Services	SCHLUMBERGER [SLB]	5.54% (6.44%)	5.79% (4.03%)	5.66% (5.24%)
5 Oil & Gas Refining & Marketing	IMPERIAL OIL [IMO]	3.92% (5.1%)	4.19% (5.06%)	4.05% (5.08%)
6 Gold	BARRICK GOLD CORP. [ABX]	4.31% (3.55%)	4.21% (3.05%)	4.26% (3.30%)
CONGLOMERATES		NN Mean (Stdev)	OLS Mean (Stdev)	Average Mean (Stdev)
7 Conglomerates	GENERAL ELECTRIC CO. [GE]	7.44% (7.18%)	6.62% (5.98%)	7.03% (6.58%)
CONSUMER GOODS		NN Mean (Stdev)	OLS Mean (Stdev)	Average Mean (Stdev)
8 Trucks & Other Vehicles	PACCAR INC. [PCAR]	3.73% (3.8%)	9.28% (4.9%)	6.50% (4.35%)
9 Auto Parts	JOHNSON CONTROLS INC. [JCI]	6.14% (6.87%)	6% (6.28%)	6.07% (6.58%)
10 Personal Products	PROCTER & GAMBLE CO. [PG]	5.9% (5.21%)	9.01% (6.74%)	7.45% (5.97%)
FINANCIAL INDUSTRY		NN Mean (Stdev)	OLS Mean (Stdev)	Average Mean (Stdev)
11 Asset Management	T. ROWE PRICE GROUP INC. [TROW]	3.29% (4.48%)	5.81% (3.62%)	4.55% (4%)
12 Money Center Banks	JPMORGAN CHASE & CO. [JPM]	3.79% (3.48%)	7% (7%)	5.4% (5.24%)
13 Diversified Investments	MORGAN STANLEY [MS]	4.86% (5.37%)	9% (7%)	6.93% (6.19%)
14 Investment Brokerage-National	CHARLES SCHWAB [SCHW]	3% (4.27%)	5% (4%)	4% (4.13%)
15 REIT - Diversified	PLUM CREEK TIMBER CO. INC. [PCL]	2.10% (2.28%)	1.93% (2.15%)	2.01% (2.21%)
16 REIT - Healthcare Facilities	HCP INC. [HCP]	2.33% (2.11%)	24.80% (4%)	13.56% (3.05%)
17 REIT - Hotel/Motel	HOST HOTELS & RESORTS INC. [HST]	3.41% (3.53%)	9.96% (3.47%)	6.68% (3.50%)
18 REIT - Industrial	PUBLIC STORAGE [PSA]	2.78% (3.13%)	6.96% (3.25%)	4.87% (3.19%)
19 REIT - Office	BOSTON PROPERTIES INC. [BXP]	2.25% (2.61%)	6.31% (2.22%)	4.28% (2.42%)
20 REIT - Retail	SIMON PROPERTY GROUP INC. [SPG]	3.19% (3.05%)	7.02% (5.33%)	5.11% (4.19%)

Table 3: Mean And Standard Deviation Of The % Forecasting Error				
BASIC MATERIALS INDUSTRY	COMPANIES	NN Mean (Stdev)	OLS Mean (Stdev)	Average Mean (Stdev)
HEALTHCARE		NN Mean (Stdev)	OLS Mean (Stdev)	Average Mean (Stdev)
21 Drug Manufacturers - Major	JOHNSON & JOHNSON [JNJ]	6.26% (5.92%)	9.36% (6.51%)	7.81% (6.21%)
22 Biotechnology	AMGEN INC. [AMGN]	7.58% (6.78%)	6.78% (6.34%)	7.18% (6.56%)
INDUSTRIAL GOODS		NN Mean (Stdev)	OLS Mean (Stdev)	Average Mean (Stdev)
23 Farm & Construction Machinery	CATERPILLAR INC. [CT]	5.48% (6.61%)	6.41% (6.68%)	5.95% (6.64%)
24 General Building Materials	VULCAN MATERIALS CO. [VMC]	4.47% (4.60%)	5.23% (4.84%)	4.85% (4.72%)
25 General Contractors	EMCOR GROUP INC. [EME]	6.06% (6.41%)	8.45% (8.30%)	7.25% (7.35%)
26 Heavy Construction	MCDERMOTT INTERNATIONAL INC. [MDR]	2.81% (3.9%)	4.59% (4.61%)	3.70% (4.26%)
27 Industrial Equipment & Component	EMERSON ELECTRIC CO. [EMR]	11.30% (10.94%)	8.26% (8.64%)	9.78% (9.79%)
28 Metal Fabrication	PRECISION CASTPARTS CORP. [PCP]	2.67% (2.28%)	3.93% (2.74%)	3.30% (2.51%)
SERVICES		NN Mean (Stdev)	OLS Mean (Stdev)	Average Mean (Stdev)
29 Air Delivery & Freight Services	FEDEX CORPORATION [FDX]	12.31% (12.28%)	16.18% (9.43%)	14.24% (10.86%)
30 Auto Parts Wholesale	GENUINE PARTS CO. [GPC]	5.78% (5.21%)	7.30% (6.10%)	6.54% (5.65%)
31 Home Improvement Stores	THE HOME DEPOT INC. [HD]	10.54% (14.92%)	7.84% (12.30%)	9.19% (13.61%)
32 Industrial Equipment Wholesale	W.W. GRAINGER INC. [GWW]	7.19% (6.70%)	7.89% (6.54%)	7.54% (6.62%)
33 Jewelry Stores	TIFFANY & CO. [TIF]	6.34% (6.18%)	6.52% (5.96%)	6.43% (6.07%)
34 Railroads	BURLINGTON NORTHERN SANTA FE CORP. [BNI]	7.50% (8.19%)	6.42% (5.30%)	6.96% (6.74%)
35 Trucking	JB HUNT TRANSPORT SERVICES INC. [JBHT]	6.53% (6.78%)	6.81% (5.91%)	6.67% (6.34%)
UTILITIES		NN Mean (Stdev)	OLS Mean (Stdev)	Average Mean (Stdev)
36 Electric Utilities	SOUTHERN COMPANY [SO]	4.55% (3.46%)	5.19% (3.88%)	4.86% (3.67%)
37 Gas Utilities	TRANSCANADA CORP. [TRP]	3.15% (2.93%)	10.66% (4.44%)	6.90% (3.69%)

Table 5: Paired T-Test Results							
		Paired Differences			t	df	Sig. 2-tailed
		Mean	Std. Deviation	Std. Error Mean			
Pair 1	BHPNN - BHPOLS	-6.34259E-4	3.42404730E-2	2.777269095E-3	-.228	151	.820
Pair 2	XOMNN - XOMOLS	-6.67665E-2	4.21730911E-2	3.420689389E-3	-19.518	151	.000
Pair 3	RIGNN - RIGOLS	-3.41046E-2	5.74627710E-2	4.660846189E-3	-7.317	151	.000
Pair 4	SLBNN - SLBOLS	-2.50065E-3	5.95664222E-2	4.831447483E-3	-.518	151	.606
Pair 5	IMONN - IMOOLS	-2.72088E-3	3.42164416E-2	2.775314989E-3	-.980	151	.328
Pair 6	ABXNN - ABXOLS	9.56043E-4	2.98818579E-2	2.423738473E-3	.394	151	.694
Pair 7	GENN - GEOLS	8.20936E-3	4.67522987E-2	3.792112164E-3	2.165	151	.032
Pair 8	PCARNN - PCAROLS	-5.54600E-2	5.08675418E-2	4.125902466E-3	-13.442	151	.000
Pair 9	JCINN - JCIOLS	1.41944E-3	4.26025544E-2	3.455523462E-3	.411	151	.682
Pair 10	PGNN - PGOLS	-3.11020E-2	6.69933325E-2	5.433876806E-3	-5.724	151	.000
Pair 11	TROWNN - TROWOLS	-2.51645E-2	4.53672736E-2	3.679771800E-3	-6.839	151	.000
Pair 12	JPMNN - JPMOLS	-3.55717E-2	6.70021588E-2	5.434592715E-3	-6.545	151	.000
Pair 13	MSNN - MSOLS	-3.97635E-2	8.04816222E-2	6.527921567E-3	-6.091	151	.000
Pair 14	SCHWNN - SCHWOLS	-1.75567E-2	4.50929150E-2	3.657518384E-3	-4.800	151	.000
Pair 15	PCLNN - PCLOLS	7.140248E0	3.13463572E1	2.5425253142E0	2.808	151	.006
Pair 16	HCPNN - HCPOLS	-2.24665E-1	4.34806491E-2	3.526746345E-3	-63.703	151	.000
Pair 17	HSTNN - HSTOLS	-6.54900E-2	5.64878909E-2	4.581772975E-3	-14.294	151	.000
Pair 18	PSANN - PSAOLS	-4.18075E-2	3.48384639E-2	2.825772567E-3	-14.795	151	.000
Pair 19	BXPNN - BXPOLS	-4.05686E-2	3.06940199E-2	2.489613771E-3	-16.295	151	.000
Pair 20	SPGNN - SPGOLS	-3.82876E-2	5.24715328E-2	4.256003314E-3	-8.996	151	.000
Pair 21	JNJNN - JNJOLS	-3.10540E-2	6.83283382E-2	5.542160068E-3	-5.603	151	.000
Pair 22	AMGNNN - AMGNOLS	8.01284E-3	4.93690931E-2	4.004362293E-3	2.001	151	.047
Pair 23	CTNN - CTOLS	-9.33403E-3	4.63714383E-2	3.761220316E-3	-2.482	151	.014
Pair 24	VMCNN - VMCOLS	-7.67446E-3	3.66897808E-2	2.975934195E-3	-2.579	151	.011
Pair 25	EMENN - EMEOLS	-2.38353E-2	5.79509746E-2	4.700444729E-3	-5.071	151	.000
Pair 26	MDRNN - MDROLS	-1.77961E-2	3.27104313E-2	2.653166327E-3	-6.708	151	.000
Pair 27	EMRNN - EMROLS	3.04359E-2	7.95976401E-2	6.456221149E-3	4.714	151	.000
Pair 28	PCPNN - PCPOLS	-1.26224E-2	3.13628082E-2	2.543859660E-3	-4.962	151	.000
Pair 29	FDXNN - FDXOLS	-3.86884E-2	1.27169704E-1	1.031482510E-2	-3.751	151	.000
Pair 30	GPCNN - GPCOLS	-1.52066E-2	4.97985906E-2	4.039199035E-3	-3.765	151	.000
Pair 31	HDNN - HDOLS	2.70019E-2	8.27355383E-2	6.710738305E-3	4.024	151	.000
Pair 32	GWWNN - GWWOLS	-7.02212E-3	5.36681089E-2	4.353058445E-3	-1.613	151	.109
Pair 33	TIFNN - TIFOLS	-1.82811E-3	4.31806947E-2	3.502416833E-3	-.522	151	.602
Pair 34	BNINN - BNIOLS	1.08634E-2	7.21605544E-2	5.852993843E-3	1.856	151	.065
Pair 35	JBHTNN - JBHTOLS	-2.81620E-3	5.55325362E-2	4.504283478E-3	-.625	151	.533
Pair 36	SONN - SOOLS	-6.40091E-3	3.60359912E-2	2.922904856E-3	-2.190	151	.030
Pair 37	TRPNN - TRPOLS	-7.51490E-2	3.87235412E-2	3.140893949E-3	-23.926	151	.000

Finally, we conducted a paired-t test to measure the performance between two models by using the ((% NN error) – (% OLS error)). Based on the result from paired t-test shown in Table 5, 19 out of 27 pairs show that NN is a better predictor. Table 6 shows the results of an aggregated paired-t test. The significance is 0.000 and we reject the Ho that OLS better predicts stock prices. The negative sign in the t-statistics shows that NN has lower errors compared to the OLS model.

Table 6: Aggregated Paired T-Test Results

		Paired Differences					t	df	Sig. (2-tailed)
		Mean	Std. Deviation	Std. Error Mean	95% Confidence Interval of the Difference				
					Lower	Upper			
Pair 1	NN - OLS	-0.0238	0.068720	0.0009161	-0.02565	-0.02206	-26.044	5625	.000

CONCLUSION AND FUTURE DIRECTION

The stock market is made of market participants with various risk and return characteristics, different perceptions and expectations about stocks and the economy, and how they interpret and react to the news. Each investor reacts to the market differently at a given point in time, focuses on different pieces of relevant information, and reaches different conclusions. It is unclear how important and how long are the impact of various pieces of information and economic data on the stock prices.

We observed that NN models have more consistent performance compared to OLS models. For example, the mean and standard deviation of errors in HCP Inc. are 2.33% and 2.11% for NN model and 24.80% and 4% for OLS model. Because OLS is a linear model, OLS possess higher variability or inconsistent performance when being used to a dataset with either positive or negative concentrated value. When OLS model took the average of positive or negative only dataset, the prediction will eventually understate or overstate the actual number. In HCP case, OLS model prediction overstated 152 out of 152 actual values by 14% to 30%. On the other hand, OLS model prediction understated 150 out of 152 actual values by 1.1% to 20.51% for Host Hotels and Resorts Inc. [HST]. As a result, mean and standard deviation of errors in HST are 3.41% and 3.53% for NN model and 9.96% and 3.47% for OLS model.

NN model had 272 surviving variables while OLS had 26 to 55 surviving variables. We found that the OLS model is easy to use and validate. It also works fast. However, it is a linear model with a relatively higher error to forecast non-linear environment in the stock market. Also, it only traced one dependent variable at a time.

In contrast, the NN model is complex and required more efforts to train the network repeatedly to find the best model. Some critical factors may create the best model such as the network architecture (number of layers and neurons) and design (logistic/ hyperbolic tangent/ linear), training algorithms, and stop training conditions (number of iterations). Although we can choose low MSE, this does not guarantee that it is the best model because the network might be over-trained causing memorization rather than learning. The Alyuda NeuroIntelligence used different sets of data each time we ran the network to avoid the memorization. The software can only reveal what is the best network architecture. Since it was an exhaustive and blind search, we cannot be certain if the model is the best or not when it comes to train the network. With these uncertainties, it was hard to measure the performance of the neural network. It will require more time to train and learn how to use the neural network.

Our results showed that NN did a better job than OLS model. Furthermore, our paper showed a significant contribution to the financial forecasting where we saw how one industry affected others. We also learned that data normalization can make a sizeable difference to the results.

One of our research limitations was that we were only comparing two methods while there might be other possible models that may be considered and tested. Furthermore, researchers might include more techniques to find the best model for financial forecasting purpose especially for a learning algorithm that can handle market shocks, financial crisis, and business cycles. Finally, there are many other learning algorithms in the NN to be explored.

REFERENCES

Aiken, M., & Bsat, M. (1999). "Forecasting Market Trends with Neural Networks," *Information Systems Management*, 16, pp. 42–49.

Allen, F. & Karjalainen, R. (1999). "Using Genetic Algorithm to Find Technical Trading Rules," *Journal of Financial Economics*, 51, pp 245-271.

Alyuda NeuroIntelligence. (2010). *Alyuda NeuroIntelligence Manual*. (http://www.alyuda.com/neural-networks-software.htm).

Aminian, F., Suarez, E., Aminian, M., & Walz, D. (2006). "Forecasting Economic Data with Neural Networks," *Computational Economics*, 28, pp. 71–88.

Balvers, R., Wu, R., & Gilliand, E. (2000). "Mean Reversion Across National Stock Markets and Parametric Contraian Investment Strategies," *Journal of finance,* 55, pp. 745-772.

Barber, B. & Odean, T. (2000). "Trading is Hazardous to your Wealth: The Common Stock Investment Performance of Individual Investors," *, Journal of Finance,* 55, pp. 773-806.

Brainmaker, (2010). California Scientific. (http://www.calsci.com/BrainMaker.html)

Blume, L. Easley, & O'Hara, M. (1994). "Market Statistics and Technical Analysis: The Role of Volume," *Journal of Finance,* 49, pp. 153-181.

Brock, W., Lakonishok, J. & LeBaron, B. (1992). "Simple Technical Trading rules and the Stochastic Properties of Stock Returns, *Journal of Finance,* 47, pp1731-1764.

Burstein, F., & Holsapple, C. (2008). *Handbook on Decision Support System 2*. Springer Berlinn Heidelbert, 175-193.

Cao, Q., Leggio, K., & Schniederjans, M. (2005). "A Ccomparison between Fama and French's Model and Artificial Networks in Predicting the Chinese Stock Market," *Computers and Operations Research*, 32, 2499–2512.

Chordia, T. & Swaminathan, B. (2000). "Trading Volume and Cross-Autocorrelations in Stock Reutrns,' *Journal of Finance,* 55, pp.913-935.

Dayhoff, J. (1990). *Neural Network Architectures: An Introduction*. New York: Van Nostrand Reinhold.

Daniel, K. Hirshleifer, D. & Subrahmanyam, A. (1998). "Investor Psychology and Security Market Under- and Overreactions," *Journal of Finance*, 53, pp.1839-1885.

De Bondt, W. & Thaler, R. (1985). "Does the Stock Market Overreact?" *Journal of Finance*, 40, pp.793-805.

DeBondt, W. & Thaler, R. (1987). "Further Evidence on Investor Overreaction and Stock Market Seasonality, 42, pp. 557-581.

DuMouchel, W. (1999). "Bayesian Data Mining in Large Frequency Tables - with an Application to the FDA Spontaneous," *American Statistician*, 53, p. 177.

Dutta, G. Jha, P. , Laha, A. & Mohan, N. (2006). "Artificial Neural Network Models for Forecasting Stock Price Index in the Bombay Stock Exchange," *Journal of Emerging Market Finance,"* 5, pp. 283-295.

Easterwoo, J. & Nutt, S. (1999). "Inefficiency in Analysts' Earnings Forecasts: Systematic Misreaction or Systematic Optimism?" *Journal of Finance,* 54, pp. 1777-1797.

Fama, E. (1970). "Efficient Capital Market: A Review of Theory and Empirical Work," *Journal of Finance*, 25,. 383-417.

Fama, E. & French, K. (1993). "Common Risk Factors in Returns on Stocks and Bonds," *Journal of Financial Economics,* 33, pp.3-56.

Ferson, W., & Harvey, C. (1993). "The Risk and Predictability of International Equity Returns," *Review of Financial Studies*, 6, pp. 527–566.

Giudici, P. (2001). "Bayesian Data Mining, with Application to Benchmarking and Credit Scoring," *Applied Stochastic Models in Business & Industry,* 17, pp. 69-81.

Gorr, W., Nagin, D., & Szczypula, J. (1994). "Comparative Study of Artificial Neural Network and Statistical Models for Predicting Student Point Averages," *International Journal of Forecasting*, 10, pp. 17–34.

Grudnitski, G., & Osburn, L. (1993). "Forecasting S&P and Gold Futures Prices: An Application of Neural Network," *Journal of Futures Markets*, 13, pp. 631-643.

Gutierrez, R. & Kelley, E. (2008). "The Long-Lasting Momentum in Weekly Returns," *Journal of Finance*, 63, 415-447

Hammad, A., Ali, S., & Hall, E. (2009). "Forecasting the Jordanian Stock Price using Artificial Neural Network," http://www.min.uc.edu/robotics/papers/paper2007/Final%20ANNIE%2007%20Souma%20Alhaj%20Ali%206p.pdf)

Han, J., & Kamber, M. (2006). *Data Mining: Concepts and Techniques*. 2nd Edition. Morgan Kaufmann, page 5.

Hess, A., & Frost, P. (1982). "Tests for Price Effects of New Issues of Seasoned Securities," *Journal of Finance*, 36, pp. 11-25.

Hirshleifer, D. (2001). "Investor Psychology and Asset Pricing," *Journal of Finance*, 56, pp. 1533-1597.

Hong, H. & Stein, J. (1999). "A Unified Theory of Underreaction, Momemtum Trading, and Overreaction in Asset Markets," *Journal of Finance*, 54, pp. 2143-2184.

Jegadeesh, N. & Titman, S. (1993). "Returns to Buying Winners and Selling Losers: Implications for Market Efficiency,' *Journal of Fiunance,* 48, pp.65-92.

Jeong, H., Song, S., Shin, S., & Cho, B. (2008). "Integrating Data Mining to a Process Design Using the Robust Bayesian Approach," *International Journal of Reliability, Quality & Safety Engineering*. 15, pp. 441-464.

Kahn, M. (2006). *Technical Analysis Plain and Simple: Charting the Markets in Your Language*. Financial Times, Prentice Hall Books.

Kahneman, D. & Riepe, M. (1998). "Aspects of Investor Psychology," *Journal of Portfolio Mnagement*, 24, 52-65.

Kahneman, D., Slovic, P. & Tversky, (1982). A. *Judgment under Uncertainty: Heuristics and Biases,* Cambridge: Cambridge University Press.

Kahneman, D. & Tversky, A. (1979). "Prospect Theory: An Analysis of Decision under Risk," *Econometrica*, 47, pp. 263-291.

Kimoto, T., Asakawa, K., Yoda, M., & Takeoka, M. (1990). "Stock Market Prediction System with Modular Neural Networks," *Proceedings of the IEEE International Conference on Neural Networks*, pp. 1–16.

Kohzadi, N., Boyd, M., Kemlanshahi, B., & Kaastra, I. (1996). "A Comparison of Artificial Neural Network and Time Series Models for Forecasting Commodity Prices," *Neurocomputing*, 10, pp. 169–181.

Kryzanowski, L., Galler, M., & Wright, D. (1993). "Using Artificial Neural Networks to Pick Stocks," *Financial Analysts Journal*, 49, pp. 21–27.

Leigh, W., Hightower, R., & Modani, N. (2005). "Forecasting the New York Stock Exchange Composite Index with Past Price and Interest Rate on Condition of Volume Spike," *Expert Systems with Applications*, 28, pp. 1–8.

Lo, A, Mamaysky, H. & Wang, J. (2000). "Foundations of technical Analysis: Computational Algorithms, Statistical Inference, and Empirical Implementation," *Journal of Finance,* 55, pp. 1705-1765.

McGrath, C. (2002). "Terminator Portfolio," *Kiplinger's Personal Finance*, 56, pp. 56–57.

McNelis, P. (1996). "A Neural Network Analysis of Brazilian Stock Prices: Tequila Effects vs. Pisco Sour Effects," *Journal of Emerging Markets*, 1, pp. 29–44.

Menzly, L. & Ozbas, O. (2010). "Market Segmentation and Cross-predictability of Returns," *Journal of Finance*, 65, pp. 1555-1580.

Moshiri, S., & Cameron, N. (2000). "Neural Network versus Econometric Models in Forecasting Inflation," *Journal of Forecasting*, 19, pp. 201-217.

Mostafa, M. (2004). "Forecasting the Suez Canal Traffic: A Neural Network Analysis," *Maritime Policy and Management*, 31, pp. 139–156.

Mostafa, M. (2010). "Forecasting Stock Exchange Movements using Neural Networks: Empirical evidence from Kuwait," *Expert Systems with Application*, 37, pp. 6302-6309.

Nam, K., & Yi, J. (1997). "Predicting Airline Passenger Volume," *Journal of Business Forecasting Methods and Systems*, 16, pp. 14–17.

Neely, C, Weller, P., & Dittmar, R. (1997). "Is Technical Analysis in the Foreign Exchange Market Profitable? A Genetic Programming Approach," *Journal of Financial and Quantitative Analysis,* pp. 405-426.

Neftci, S. (1991). "Naïve Trading Rules in Financial Market and Wiener-Komogorov Prediction Theory: A Study of Technical Analysis," *Journal of Business, 64, pp.549-571.*

Nofsinger, J., & Sias, R. (1999). "Herding and Feedback Trading by Institutional and Individual Investors," *Journal of Finance*, 54, pp. 2263-2295.

Odean, T. (1998). "Volume, Volatility, Price, and Profits When All Traders Are Above Average," *Journal of Finance,*53, pp. 1887-1934.

Odean, T. (1999). "Do Investors Trade too Much?" *American Economic Review,* 89, pp. 1279-1298.

Poh, H., Yao, J., & Jasic, T. (1998). "Neural Networks for the Analysis and Forecasting of Advertising Impact," *International Journal of Intelligent Systems in Accounting, Finance and management*, 7, pp. 253–268.

Pruitt, S. & White, R. (1988). "The CRISMA Trading System: Who Says Technical Analysis Can't Beat the Market?"*Journal of Portfolio Management,*14, pp.55-58.

Ruiz-Suarez, J., Mayora-Ibarra, O., Torres -Jimenez, J., & Ruiz-Suarez, L. (1995). "Short-term Ozone Forecasting by Artificial Neural Network," *Advances in Engineering Software*, 23, pp. 143–149.

Shefrin, H. (2000). *Beyond Greed and Fear Understanding Behavioral Finance and the Psychology of Investing,* Boston: Harvard Business School.

Shleifer, A. (2000). *Inefficient Markets: An Introduction to Behavioral Finance*, New York: Oxford University Press.

Shiller, R. (2000). *Irrational Exuberance,* Princeton: Princeton University Press.

Shiller, R. (2002). "Bubble, Human judgment, and Expert Opinion," *Financial Analyst Journal*, 58, pp.18-26.

Shiller, R. (2003). "From Efficient Market Theory to Behavioral Finance," *Journal of Economic Perspectives,* 17, pp. 83-104.

Simon, H. (1955). "A Behavioral Model of Rational Choice," *Quarterly Journal of Economics,* 69, pp. 99-118.

Simon, H. (1982). *Models of Bounded Rationality*, Vol. 2, *Behavioral Economics and Business organization,* Cambridge: the MIT Press.

Simon, H. (1997). *Models of Bounded Rationality*, Vol. 3, *Empirically Grounded Economic Reason,* Cambridge: the MIT Press.

Sullivan, R., Timmermann, A. & White, H. (1999). "Data-Snooping, Technical Trading Rule Performance, and the Bootstrap," *Journal of Finance*, 54, pp. 1647-1691.

Thaler, R. (ed.) (2005). *Advances in Behavioral Finance,* Vol. 2, New York: Russell Sage Foundation, Princeton University Press.

Tjung, L., Kwon, O., Tseng, K., & Bradley-Geist, J. (2010). "Forecasting Financial Stocks using Data Mining," *Global Economy and Finance Journal*, 3(2), pp. 13 - 26.

Tokic, D. (2005). "Explaining US Stock Market Returns from 1980 to 2005," *Journal of Asset Management*, 6, pp. 418-432.

Tsai, C.-F. & Wang, S.-P. (2009). Stock Price Forecasting by Hybrid Machine Learning Techniques," *Proceedings of InternationalMultiConference of Engineers and Computer Scientists*, 1.

Tseng, K. (2004). "Panorama of NASDAQ Stock Bubbles and Aftermath," *American Business Review,* 22, 61-71.

Tseng, K.C. (2006). "Behavioral Finance, Bounded Rationality, Nero-Finance, and Traditional Finance," *Investment Management and Financial Innovations*, 3, pp. 7-18

Turban, E. (1992). *Expert Systems and Applied Aartificial Intelligence*. New York: Macmillan Publishing Company.

Tveter, D. (2000). "The Backpropagation Algorithm," retrieved on March 10, 2010 from http://www.dontveter.com

Videnova, I., Nedialkova, D., Dimitrova, M., & Popova, S. (2006). "Neural Networks for Air Pollution Forecasting," *Applied Artificial Intelligence*, 20, pp. 493-506.

West, P., Brockett, P., & Golden, L. (1997). "A Comparative Analysis of Neural Networks and Statistical Methods for Predicting Consumer Choice," *Marketing Science,* 16, pp. 370-391.

Ying, J., Kuo, L. & Seow, G, (2005). "Forecasting Stock Prices Using a Hierarchical Bayesian Approach,"*Journal of Forecasting*, 24, pp. 39-59.

Yoon, Y., & Swales, G. (1991) "Predicting Stock Price Performance: A Neural Network Approach," *Proceedings of the IEEE 24th Annual International Conference of Systems Sciences*, pp.156-162.

Yu, L., Wang, S., & Lai, K. (2009). "A Neural-Network-based Nonlinear Metamodeling Approach to Financial Time Series Forecasting," *Applied Soft Computing*, 9, pp. 563–574.

Yumlu, S., Gurgen, F., & Okay, N. (2005). "A Comparison of global, Recurrent and Smoothed-Piecewise Neural Models for Istanbul Stock Exchange (ISE) Prediction," *Pattern Recognition Letters*, 26, pp. 2093–2103.

Zhuo, W., Li-Min, J., Yong, Q., & Yan-hui, W. (2007). "Railway Passenger Traffic Volume Prediction based on Neural Network," *Applied Artificial Intelligence*, 21, pp. 1–10.

APPENDIX

Table A1: Macroeconomic indicators	
AEX	Amsterdam Price
CAC	Paris Price
DAX	German Index
FTSE	FTSE Index Price
SMI	Swiss Market Index
STI	Straits Times Index Singapore
IPC	Mexico Index
HSI	Hang Seng Index
BSE	Bombay Stock Exchange Sensex
BVSP	Bovespa-Brazillian Index
ATX	Vienna Stock Exchange
MERV	Merval Buenos Aires Index
KLSE	FTSE Bursa Malaysia Klci
TSEC	Taiwan Weighted Index
KOSPI	Kospi Composite Index
N225	Nikkei 225
JKSE	Jakarta Stock Exchange Index
TA	Tel Aviv 100
(World Indexes)Source: YahooFinance	

Table A2: Microeconomic indicators	
BASIC MATERIALS	**COMPANIES**
1 Agricultural Chemicals	POTASH CP SASKATCHEWAN [POT]
2 Aluminum	ALCOA INC [AA]
3 Chemicals - Major Diversified	DOW CHEMICAL [DOW]
4 Copper	FREEPORT MCMORAN [FCX]
5 Gold	BARRICK GOLD [ABX]
6 Independent Oil & Gas	OCCIDENTAL PETROLEUM [OXY]
7 Industrial Metals & Minerals	BHP BILLITON [BHP]
8 Major Integrated Oil & Gas	EXXON MOBIL [XOM]
9 Nonmetallic Mineral Mining	HARRY WINSTON DIAMOND [HWD]
10 Oil & Gas Drilling & Exploration	TRANSOCEAN [RIG]
11 Oil & Gas Equipment & Services	SCHLUMBERGER [SLB]
12 Oil & Gas Pipelines	KINDER MORGAN ENERGY PARTNERS [KMP]
13 Oil & Gas Refining & Marketing	IMPERIAL OIL [IMO]
14 Silver	COEUR D' ALENE MINES COPR [CDE]

Table A2: Microeconomic indicators	
BASIC MATERIALS	**COMPANIES**
15 Specialty Chemicals	LUBRIZOL CORP [LZ]
16Steel & Iron	RIO TINTO PLC [RTP]
17 Synthetics	PRAXAIR INC [PX]
CONGLOMERATES	
18 Conglomerates	GENERAL ELECTRIC [GE]
CONSUMER GOODS	
19 Appliances	WHIRLPOOL CORP [WHR]
20 Auto Manufacturers - Major	HONDA MOTOR CO. LTD [HMC]
21 Auto Parts	JOHNSON CONTROLS INC [JCI]
22 Beverages - Brewers	FORMENTO ECONOMICO MEXICANO [FMX]
23 Beverages - Soft Drinks	THE COCA-COLA CO. [KO]
24 Beverages - Wineries & Distillers	DIAGEO PLC [DEO]
25 Business Equipment	XEROX CORP. [XRX]
26 Cigarettes	BRITISH AMERICAN TOBACCO PCL [BTI]
27 Cleaning Products	ECOLAB INC [ECL]
28 Confectioners	CADBURY PLC [CBY]
29 Dairy Products	LIFEWAY FOODS INC [LWAY]
30 Electronic Equipment	SONY CORPORATION [SNE]
31 Farm Products	ARCHER-DANIELS-MIDLAND [ADM]
32 Food - Major Diversified	HJ HEINZ CO. [HNZ]
33 Home Furnishings & Fixtures	FORTUNE BRANDS INC [FO]
34 Housewares & Accessories	NEWELL RUBBERMAID INC [NWL]
35 Meat Products	HORMEL FOODS CORP. [HRL]
36 Office Supplies	ENNIS INC. [EBF]
37 Packaging & Containers	OWENS-ILLINOIS [OI]
38 Paper & Paper Products	INTERNATIONAL PAPER CO. [IP]
39 Personal Products	PROCTER & GAMBLE CO. [PG]
40 Photographic Equipment & Supplies	EASTMAN KODAK [EK]
41 Processed & Packaged Goods	PEPSICO INC. [PEP]
42 Recreational Goods, Other	FOSSIL INC. [FOSL]
43 Recreational Vehicles	HARLEY-DAVIDSON INC. [HOG]
44 Rubber & Plastics	GOODYEAR TIRE & RUBBER CO. [GT]
45 Sporting Goods	CALLAWAY GOLF CO. [ELY]
46 Textile - Apparel Clothing	VF CORP. [VFC]
47 Textile - Apparel Footwear & Accessories	NIKE INC. [NKE]
48 Tobacco Products, Other	UNIVERSAL CORP. [UVV]
49 Toys & Games	MATTEL INC. [MAT]
50 Trucks & Other Vehicles	PACCAR INC. [PCAR]
FINANCIAL	
51 Accident & Health Insurance	AFLAC INC. [AFL]

Table A2: Microeconomic indicators	
BASIC MATERIALS	**COMPANIES**
52 Asset Management	T. ROWE PRICE GROUP INC. [TROW]
53 Closed-End Fund - Debt	ALLIANCE BERNSTEIN INCOME FUND INC. [ACG]
54 Closed-End Fund - Equity	DNP SELECT INCOME FUND INC. [DNP]
55 Closed-End Fund - Foreign	ABERDEEN ASIA-PACIFIC INCOME FUND INC. [FAX]
56 Credit Services	AMERICAN EXPRESS CO. [AXP]
57 Diversified Investments	MORGAN STANLEY [MS]
58 Foreign Money Center Banks	WESTPAC BANKING CORP [WBK]
59 Foreign Regional Banks	BANCOLOMBIA S.A. [CIB]
60 Insurance Brokers	MARSH & MCLENNAN [MMC]
61 Investment Brokerage - National	CHARLES SCHWAB CORP. [SCHW]
62 Investment Brokerage - Regional	JEFFERIES GROUP INC. [JEF]
63 Life Insurance	AXA [AXA]
64 Money Center Banks	JPMORGAN CHASE & CO. [JPM]
65 Mortgage Investment	ANALLY CAPITAL MANAGEMENT [NLY]
66 Property & Casualty Insurance	BERKSHIRE HATHAWAY [BRK-A]
67 Property Management	ICAHN ENTERPRISES, L.P. [IEP]
68 REIT - Diversified	PLUM CREEK TIMBER CO. INC. [PCL]
69 REIT - Healthcare Facilities	HCP INC. [HCP]
70 REIT - Hotel/Motel	HOST HOTELS & RESORTS INC. [HST]
71 REIT - Industrial	PUBLIC STORAGE [PSA]
72 REIT - Office	BOSTON PROPERTIES INC. [BXP]
73 REIT - Residential	EQUITY RESIDENTIAL [EQR]
74 REIT - Retail	SIMON PROPERTY GROUP INC. [SPG]
75 Real Estate Development	THE ST. JOE COMPANY [JOE]
76 Regional - Mid-Atlantic Banks	BB & T CORP. [BBT]
77 Regional - Midwest Banks	US BANCORP [USB]
78 Regional - Northeast Banks	STATE STREET CORP. [STT]
79 Regional - Pacific Banks	BANK OF HAWAII CORP. [BOH]
80 Regional - Southeast Banks	REGIONS FINANCIAL CORP. [RF]
81 Regional - Southwest Banks	COMMERCE BANCSHARES INC. [CBSH]
82 Savings & Loans	PEOPLE’S UNITED FINANCIAL INC. [PBCT]
83 Surety & Title Insurance	FIRST AMERICAN CORP. [FAF]
HEALTHCARE	
84 Biotechnology	AMGEN INC. [AMGN]
85 Diagnostic Substances	IDEXX LABORATORIES INC. [IDXX]
86 Drug Delivery	ELAN CORP. [ELN]
87 Drug Manufacturers - Major	JOHNSON & JOHNSON [JNJ]
88 Drug Manufacturers - Other	TEVA PHARMACEUTICAL INDUSTRIES LTD [TEVA]
89 Drug Related Products	PERRIGO CO. [PRGO]
90 Drugs - Generic	MYLAN INC. [MYL]

Table A2: Microeconomic indicators	
BASIC MATERIALS	**COMPANIES**
91 Health Care Plans	UNITEDHEALTH GROUP INC. [UNH]
92 Home Health Care	LINCARE HOLDINGS INC. [LNCR]
93 Hospitals	TENET HEALTHCARE CORP. [THC]
94 Long-Term Care Facilities	EMERITUS CORP. [ESC]
95 Medical Appliances & Equipment	MEDTRONIC INC. [MDT]
96 Medical Instruments & Supplies	BAXTER INTERNATIONAL INC. [BAX]
97 Medical Laboratories & Research	QUEST DIAGNOSTICS INC. [DGX]
98 Medical Practitioners	TRANSCEND SERVICES INC. [TRCR]
99 Specialized Health Services	DAVITA INC. [DVA]
INDUSTRIAL GOODS	
100 Aerospace/Defense - Major Diversified	BOEING CO. [BA]
101 Aerospace/Defense Products & Services	HONEYWELL INTERNATIONAL INC. [HON]
102 Cement	CRH PLC[CRH]
103 Diversified Machinery	ILLINOIS TOOL WORKS INC. [ITW]
104 Farm & Construction Machinery	CATERPILLAR INC. [CT]
105 General Building Materials	VULCAN MATERIALS CO. [VMC]
106 General Contractors	EMCOR GROUP INC. [EME]
107 Heavy Construction	MCDERMOTT INTERNATIONAL INC. [MDR]
108 Industrial Electrical Equipment	EATON CORPORATION [ETN]
109 Industrial Equipment & Components	EMERSON ELECTRIC CO. [EMR]
110 Lumber, Wood Production	WEYERHAEUSER CO. [WY]
111 Machine Tools & Accessories	STANLEY WORKS [SWK]
112 Manufactured Housing	SKYLINE CORP [SKY]
113 Metal Fabrication	PRECISION CASTPARTS CORP. [PCP]
114 Pollution & Treatment Controls	DONALDSON COMPANY INC. [DCI]
115 Residential Construction	NVR INC. [NVR]
116 Small Tools & Accessories	THE BLACK & DECKER CORP. [BDK]
117 Textile Industrial	MOHAWK INDUSTRIES INC. [MHK]
118 Waste Management	WASTE MANAGEMENT INC. [WM]
SERVICES	
119 Advertising Agencies	OMNICOM GROUP INC. [OMC]
120 Air Delivery & Freight Services	FEDEX CORP. [FDX]
121 Air Services, Other	BRISTOW GROUP INC. [BRS]
122 Apparel Stores	GAP INC. [GPS]
123 Auto Dealerships	CARMAX INC. [KMX]
124 Auto Parts Stores	AUTOZONE INC. [AZO]
125 Auto Parts Wholesale	GENUINE PARTS CO. [GPC]
126 Basic Materials Wholesale	AM CASTLE & CO. [CAS]
127 Broadcasting - Radio	SIRIUS XM RADIO INC. [SIRI]
128 Broadcasting - TV	ROGERS COMMUNICATIONS INC. [RCI]

Table A2: Microeconomic indicators	
BASIC MATERIALS	**COMPANIES**
129 Business Services	IRON MOUNTAIN INC. [IRM]
130 CATV Systems	COMCAST CORP. [CMCSA]
131 Catalog & Mail Order Houses	AMAZON.COM INC. [AMZN]
132 Computers Wholesale	INGRAM MICRO INC. [IM]
133 Consumer Services	MONRO MUFFLER BRAKE INC. [MNRO]
134 Department Stores	THE TJX COMPANIES INC. [TJX]
135 Discount, Variety Stores	WAL-MART STORES INC. [WMT]
136 Drug Stores	CVS CAREMARK CORP. [CVS]
137 Drugs Wholesale	MCKESSON CORP. [MCK]
138 Education & Training Services	DEVRY INC. [DV]
139 Electronics Stores	BEST BUY CO. INC. [BBY]
140 Electronics Wholesale	AVNET INC. [AVT]
141 Entertainment - Diversified	WALT DISNEY CO. [DIS]
142 Food Wholesale	SYSCO CORP. [SYY]
143 Gaming Activities	BALLY TECHNOLOGIES INC. [BYI]
144 General Entertainment	CARNIVAL CORP. [CCL]
145 Grocery Stores	KROGER CO. [KR]
146 Home Furnishing Stores	WILLIAMS-SONOMA INC. [WSM]
147 Home Improvement Stores	THE HOME DEPOT INC. [HD]
148 Industrial Equipment Wholesale	W.W. GRAINGER INC. [GWW]
149 Jewelry Stores	TIFFANY & CO. [TIF]
150 Lodging	STARWOOD HOTELS & RESORTS WORLDWIDE INC. [HOT]
151 Major Airlines	AMR CORP. [AMR]
152 Management Services	EXPRESS SCRIPTS INC. [ESRX]
153 Marketing Services	VALASSIS COMMUNICATIONS INC. [VCI]
154 Medical Equipment Wholesale	HENRY SCHEIN INC. [HSIC]
155 Movie Production, Theaters	MARVEL ENTERTAINMENT INC. [MVL]
156 Music & Video Stores	BLOCKBUSTER INC. [BBI]
157 Personal Services	H&R BLOCK INC. [HRB]
158 Publishing - Books	THE MCGRAW-HILL CO. INC. [MHP]
159 Publishing - Newspapers	WASHINGOTN POST CO. [WPO]
160 Publishing - Periodicals	MEREDITH CORP. [MDP]
161 Railroads	BURLINGTON NORTHERN SANTA FE CORP. [BNI]
162 Regional Airlines	SOUTHWEST AIRLINES CO. [LUV]
163 Rental & Leasing Services	RYDER SYSTEM INC. [R]
164 Research Services	PAREXEL INTL CORP. [PRXL]
165 Resorts & Casinos	MGM MIRAGE [MGM]
166 Restaurants	MCDONALD'S CORP. [MCD]
167 Security & Protection Services	GEO GROUP INC. [GEO]
168 Shipping	TIDEWATER INC. [TDW]

Table A2: Microeconomic indicators	
BASIC MATERIALS	**COMPANIES**
169 Specialty Eateries	STARBUCKS CORP. [SBUX]
170 Specialty Retail, Other	STAPLES INC. [SPLS]
171 Sporting Activities	SPEEDWAY MOTORSPORTS INC. [TRK]
172 Sporting Goods Stores	HIBBETT SPORTS INC. [HIBB]
173 Staffing & Outsourcing Services	PAYCHEX INC. [PAYX]
174 Technical Services	JACOBS ENGINEERING GROUP INC. [JEC]
175 Trucking	JB HUNT TRANSPORT SERVICES INC. [JBHT]
176 Wholesale, Other	VINA CONCHA Y TORO S.A. [VCO]
TECHNOLOGY	
177 Application Software	MICROSOFT CORP. [MSFT]
178 Business Software & Services	AUTOMATIC DATA PROCESSING INC. [ADP]
179 Communication Equipment	NOKIA CORP. [NOK]
180 Computer Based Systems	ADAPTEC INC. [ADPT]
181 Computer Peripherals	LEXMARK INTERNATIONAL INC. [LXK]
182 Data Storage Devices	EMC CORP. [EMC]
183 Diversified Communication Services	TELECOM ARGENTINA S A [TEO]
184 Diversified Computer Systems	INTERNATIONAL BUSINESS MACHINES CORP. [IBM]
185 Diversified Electronics	KYOCERA CORP. [KYO]
186 Healthcare Information Services	CERNER CORP. [CERN]
187 Information & Delivery Services	DUN & BRADSTREET CORP. [DNB]
188 Information Technology Services	COMPUTER SCIENCES CORPORATION [CSC]
189 Internet Information Providers	YAHOO! INC. [YHOO]
190 Internet Service Providers	EASYLINK SERVICES INTERNATIONAL CORP. [ESIC]
191 Internet Software & Services	CGI GROUP INC. [GIB]
192 Long Distance Carriers	TELEFONOS DE MEXICO, S.A.B. DE C.V. [TMX]
193 Multimedia & Graphics Software	ACTIVISION BLIZZARD INC. [ATVI]
194 Networking & Communication 19Devices	CISCO SYSTEMS INC. [CSCO]
195 Personal Computers	APPLE INC. [AAPL]
196 Printed Circuit Boards	FLEXTRONICS INTERNATIONAL LTD. [FLEX]
197 Processing Systems & Products	POLYCOM INC. [PLCM]
198 Scientific & Technical Instruments	THERMO FISHER SCIENTIFIC INC. [TMO]
199 Security Software & Services	SYMANTEC CORP. [SYMC]
200 Semiconductor - Broad Line	INTEL CORP. [INTC]
201 Semiconductor - Integrated Circuits	QUALCOMM INC. [QCOM]
202 Semiconductor - Specialized	XILINX INC. [XLNX]
203 Semiconductor Equipment & Materials	APPLIED MATERIALS INC. [AMAT]
204 Semiconductor- Memory Chips	MICRON TECHNOLOGY INC. [MU]
205 Technical & System Software	AUTODESK INC. [ADSK]
206 Telecom Services - Domestic	AT&T INC. [T]
207 Telecom Services - Foreign	NIPPON TELEGRAPH & TELEPHONE CORP. [NTT]

Table A2: Microeconomic indicators	
BASIC MATERIALS	**COMPANIES**
208 Wireless Communications	CHINA MOBILE LIMITED [CHL]
UTILITIES	
209 Diversified Utilities	EXELON CORP. [EXC]
210 Electric Utilities	SOUTHERN COMPANY [SO]
211 Foreign Utilities	ENERSIS S.A. [ENI]
212 Gas Utilities	TRANSCANADA CORP. [TRP]
213 Water Utilities	AQUA AMERICA INC. [WTR]
Source: YahooFinance	

Table A.3. Market Indicators	
S&P	S&P 500's price changes
DJI	Dow Jones Industrial's price changes
DJT	Dow Jones Transportation's price changes
DJU	Dow Jones Utility's price changes
Source: YahooFinance	

Table A.4. Market Sentiment Indicators	
VIX	CBOE Volatility Index changes
VXO	CBOE OEX Volatility Index
Source: YahooFinance	

Table A.5. Institutional Investor	
BEN	FRANKLIN RESOURCES INC.

Table A.6. Politics Indicators		
Election	Presidential Election day	White House
Party	Party: Republican or Democratic	Wikipedia

Table A.7. Business Cycles	
Tech crash	Technological Crash 3/24/2000-10/9/2002
Current bear	Current bear 10/9/2007-11/16/2009

Table A.8. Calendar Anomalies	
Mon	Monday
Tue	Tuesday
Wed	Wednesday
Thurs	Thursday
Fri	Friday
W1	First week
W2	Second week
W3	Third week
W4	Fourth week
W5	Fifth week
Jan	January
Feb	February
Mar	March
Apr	April
May	May
Jun	June
Jul	July
Aug	August
Sep	September
Oct	October
Nov	November
Dec	December
pHol	Pre holiday

PREDICTING INFORMATION TECHNOLOGY ADOPTION IN SMALL BUSINESSES: AN EXTENSION OF THE TECHNOLOGY ACCEPTANCE MODEL

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ABSTRACT

Studies that examine information technology (IT) adoption in small businesses are relatively scarce. Of those studies, a few have used the Technology Acceptance Model (TAM) to predict IT adoption in a small businesses environment. Even so, the TAM still fails to explain much of the variance in computer usage. The mental model literature suggests that providing users with a diagram of how a particular technology works may be an enhancement over the current version of the TAM. In the current paper, a revised model that incorporates mental models is empirically tested. Future research aspirations are also discussed.

INTRODUCTION

There are only a handful of studies that examine information technology (IT) adoption in small businesses. This is quite surprising given that smaller firms far outnumber larger ones and contribute significantly to the economy. According to the U.S. Small Business Administration (2009), small businesses are responsible for creating many new jobs and innovations as well as contributing close to half of the U.S. GDP (1).

Moreover, research suggests that small companies face unique IT issues, such as reliance on external IT expertise (Thong, Yap & Raman, 1996). Thus, the implication is that many studies that look at IT adoption may not be applicable to small businesses. Further, the studies that have examined IT adoption in small firms all imply that an important determinant is attitude toward the technology (Riemenschneider, Harrison, & Mykytyn, Jr., 2003; Caldeira & Ward, 2003; Mirchandani & Motwani, 2001).

Attitude toward technology is an integral component of the Technology Acceptance Model (TAM). Specifically, the TAM predicts that a user's attitude toward a particular technology ultimately affects whether or not they accept that technology. In fact, the TAM has already been used to study IT adoption in small businesses (e.g., Dembla, Palvia & Krishnan, 2007; Riemenschneider, Harrison, & Mykytyn, Jr., 2003).

However, by itself, the TAM only explains about 40% of the variance in computer usage, suggesting that additional factors may help explain IT acceptance (Legris, Ingham & Collerette, 2003). Thus, the purpose of this paper is twofold. Obviously, one goal is to improve upon the TAM by proposing a revised model that incorporates elements from the mental model literature.

Most importantly, however, the goal is to offer a model that ultimately better explains IT adoption in a small business environment.

The rest of the paper is laid out as follows. First, a review of the TAM and mental model literature is provided followed by the revised model. Next, the revised model is empirically tested. Finally, limitations and future aspirations are discussed.

TECHNOLOGY ACCEPTANCE MODEL

The original form of the Technology Acceptance Model (TAM) (Davis, 1989; Davis, Bagozzi & Warshaw, 1989) is derived from the Theory of Reasoned Action (TRA), a commonly used theory from social psychology (Fishbein & Ajzen, 1975) (Figure 1). The TRA can be described as a conceptual framework that predicts whether or not an individual performs a certain behavior based on their behavioral intention (BI) to perform that behavior (16). Further, one's BI is determined by the individual's attitude (A) and subjective norm (SN) with respect to the behavior, where A is determined by one's beliefs and evaluations of the consequences related to that behavior (16). SN is determined by the individual's perception that one's referents have opinions about whether or not to perform the behavior and by the individual's motivation to comply with those referent opinions (16).

The TAM also asserts that one's behavior is determined by their intention to perform that behavior. The TAM, however, is specifically adapted to model users' acceptance of information systems (Davis, Bagozzi & Warshaw, 1989) (Figure 2). TAM posits that computer users' usage behavior is indirectly determined by two particular beliefs, *perceived usefulness* (U) and *perceived ease of use* (EOU) (985). This differs from the TRA where all beliefs are aggregated into a single construct (988).

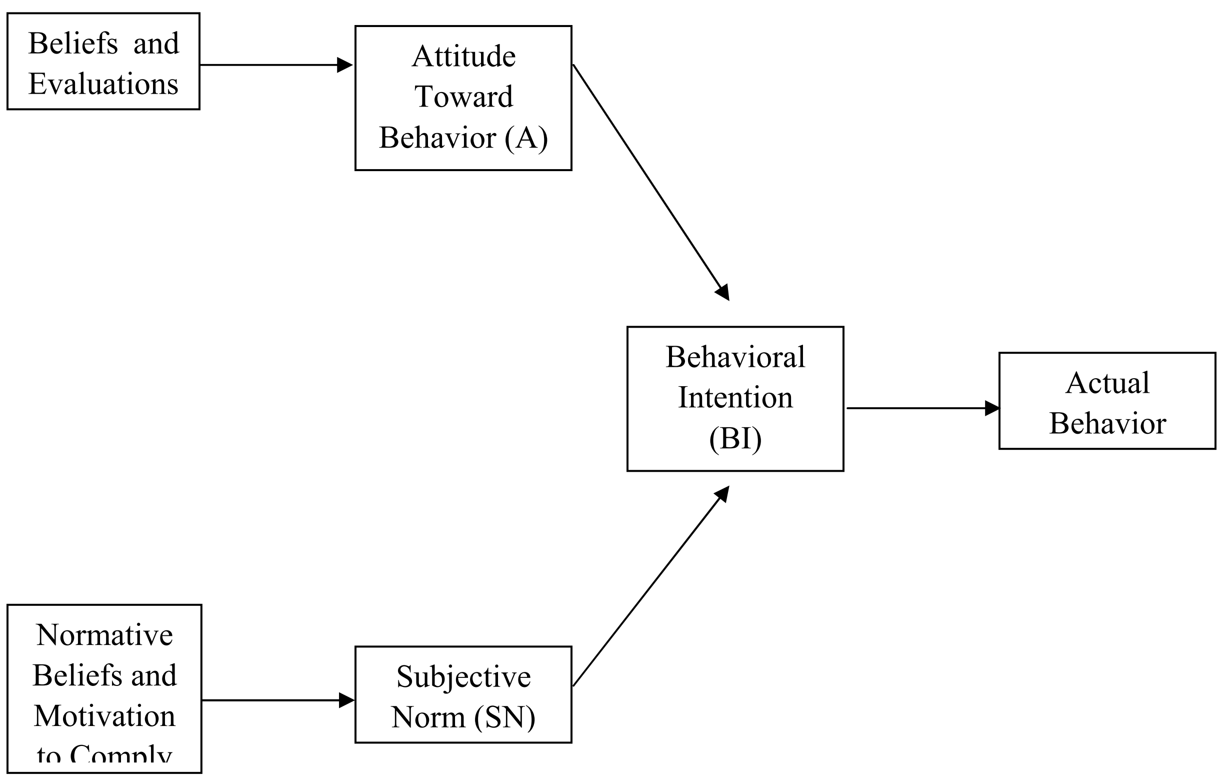
Specifically, U is defined as the "user's subjective probability that using a specific application system will increase his or her job performance within an organizational context" (985). In other words, U refers to users' beliefs that the system will help them increase their job performance. EOU is defined as "the degree to which the prospective user expects the target system to be free of effort" (985). In other words, EOU refers to users' beliefs that the system is easy to use. Both these constructs directly affect a user's attitude (A) toward using the system, which, in turn, affects the user's behavioral intention (BI) to use the system.

There are a several additional differences to note regarding the TAM. First, the TAM excludes the social norm (SN) construct from the TRA. Fishbein and Ajzen (1975) note that little research has been done regarding normative beliefs or motivation to comply with those beliefs (304), and Davis, Bagozzi, and Warshaw (1989) concur, noting that SN is the least understood component of TRA (986). As cited in Davis, Bagozzi, and Warshaw (1989), the direct effects of the SN component are difficult to disentangle from its indirect effects through A (986). Thus, because of the problematic nature of SN, the authors chose to drop this construct from their model.

Second, Davis, Bagozzi, and Warshaw (1989) posit that BI may be directly affected not only by A, but also by U. That is, their model suggests a direct link between the user's perceived usefulness of the system and his/her intention to use the system. Third, they include external variables in their model, items that directly affect U and EOU. System features, training, user support consultants, and documentation are all examples of external variables in the TAM (988). Finally, the TAM's U and EOU are expected to generalize across other systems and users. In contrast, the TRA identifies new beliefs with every new context (988).

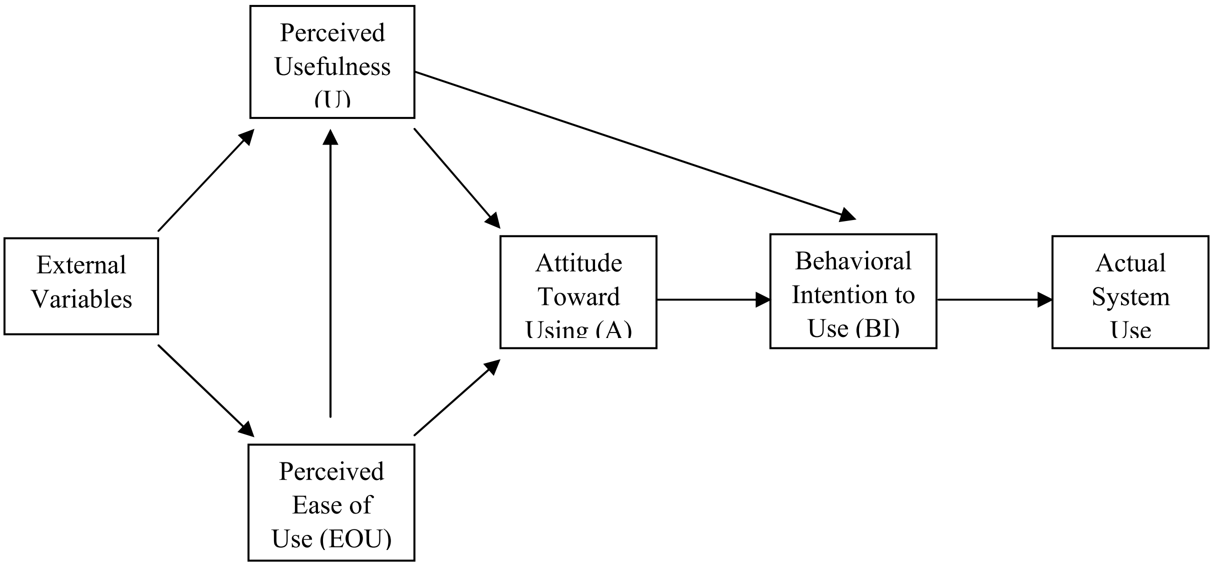
Several studies have used the TAM to study IT adoption in a small business setting (e.g., Chatzoglou, Vraimaki, Diamantidis & Sarigiannidis, 2010; Dembla, Palvia & Krishnan, 2007; Riemenschneider, Harrison, & Mykytyn, Jr., 2003). For example, in their study of web-enabled transaction processing by small businesses, Dembla, Palvia & Krishnan (2007) find that consistent with the TAM, perceived usefulness is a major determinant of adoption (10). Further, in their study of small and medium-sized businesses in Greece, Chatzoglou, Vraimaki,

Figure 1: Theory of Reasoned Action



Source: Davis, Bagozzi & Warshaw (1989

Figure 2: Technology Acceptance Model



Source: Davis, Bagozzi & Warshaw (1989)

Diamantidis and Sarigiannidis (2010) find that perceived usefulness as well as perceived ease of use are important determinants of computer acceptance. Overall, despite its potential for studying IT adoption in small businesses, the TAM still only explains, at most, about 40% of the variance in computer usage, suggesting that the current model does not include significant factors (Legris, Ingham & Collerette, 2003). Indeed, in their own study of IT adoptions in small businesses, Riemenschneider, Harrison & Mykytyn (2003) use a "combined" model that incorporates elements from the TAM and the Theory of Planned Behavior (TPB). Thus, in the spirit of furthering our ability to explain IT adoption in small businesses, it makes sense to consider additional constructs. One such construct, mental models, is discussed in the next section.

MENTAL MODELS

Mental models are defined as the user's internal representations of an object, which guide their interaction with that object (Staggers & Norcio, 1993). More specifically, a user's mental model of a computer system is their mental representation of that system, which guides their actions and helps them interpret the system's behavior (Young, 1981). Overall, mental models provide users with predictive and explanatory power for understanding their interaction with the system (Norman, 1983).

Unfortunately, prior research has coined various other terms that are used synonymously with mental models, such as conceptual models, cognitive models, mental models of discourse, component models, and causal models (Staggers & Norcio, 1993). Norman (1983) provides some clarification on this matter. He defines the *conceptual model* as an accurate, consistent, and complete model of the system that is created by teachers, designers, scientists, or engineers (7). In contrast, a user's *mental model* represents what they actually "have in their heads" and may not be the same as the conceptual model (12).

Norman's distinction between these two terms shall be used throughout the remainder of the paper. Namely, the term *conceptual model* will be used to mean a model that describes how the system should work, i.e., a blueprint. Conceptual models are thus external to the individual. On the other hand, the term *mental model* will be used to refer to the user's understanding of how the system works. In other words, a mental model is internal to the individual, representing the individual's mental template of the system.

Some of the past literature on mental models looks at how individuals form their mental models. One notion is that people use analogies to structure unfamiliar domains (Gentner & Gentner, 1983). As cited in Staggers and Norcio (1993), Douglas (1982) finds that subjects create a typewriter model when they are learning to use a text editor, indicating that individuals transfer familiar knowledge to similar, yet unfamiliar, domains (590).

Much of the past literature, however, examines how users' mental models aid in their learning process. For example, Brandt (2001) examines how users employ mental models to obtain task-specific knowledge and to help in solving problems. The literature supports the general notion that users' mental models serve as templates for understanding in a variety of contexts, including where users are using or learning to use a computer system.

Further, past research has looked at ways to help users create more useful mental models. In particular, studies have examined the benefits from providing users with a conceptual model of a system prior to training them on the system. For example, Bayman and Mayer (1984) report evidence that providing users with conceptual models helps them develop more useful mental models of the system (197). In other words, providing users with a diagram of how the system works helps them to better understand the system. Young (1981) also offers evidence that supports this conclusion. In addition to having a better understanding of the system, these studies provide evidence that users perform better as well (e.g., Bayman & Mayer, 1984; Mayer, 1981; Young, 1981).

REVISED MODEL

As mentioned in the previous section, research on mental models suggests that in order for users to interact effectively with a system, they need to create a mental representation of how the system works (e.g., Young, 1981; Brandt, 2001). This model guides users' actions and helps them interpret system behaviors (Young, 1981). Further, researchers have argued that individuals employ mental models to build their knowledge base (e.g., task-specific knowledge) and to aid in problem-solving (Brandt, 2001).

Additional evidence indicates that providing users with a conceptual model of the system beforehand aids in their understanding of the system (i.e., developing their mental model of the system) and improves their performance (Bayman & Mayer, 1984; Mayer, 1981; Young, 1981). Intuitively, this result makes sense, for it implies that users perform better when they understand how the system works. Subjects that receive conceptual models before their interaction with the system are able to develop more useful mental models of the system (i.e., a better understanding of the system), which, in turn, improves their performance.

Overall, the evidence signifies that mental models are an important aspect of the user's interaction with the computer system. Additionally, the evidence suggests that providing users with a conceptual model of the system aids them in developing a more useful mental model of the system, i.e., facilitating their understanding of how the system works. More importantly, however, this stream of research provides insight into one determinant of technology acceptance. Specifically, the results from these studies imply that providing subjects with a conceptual model of a computer system will facilitate a greater understanding of the system, which, in turn, may make the system seem easier to use (i.e., perceived ease of use).

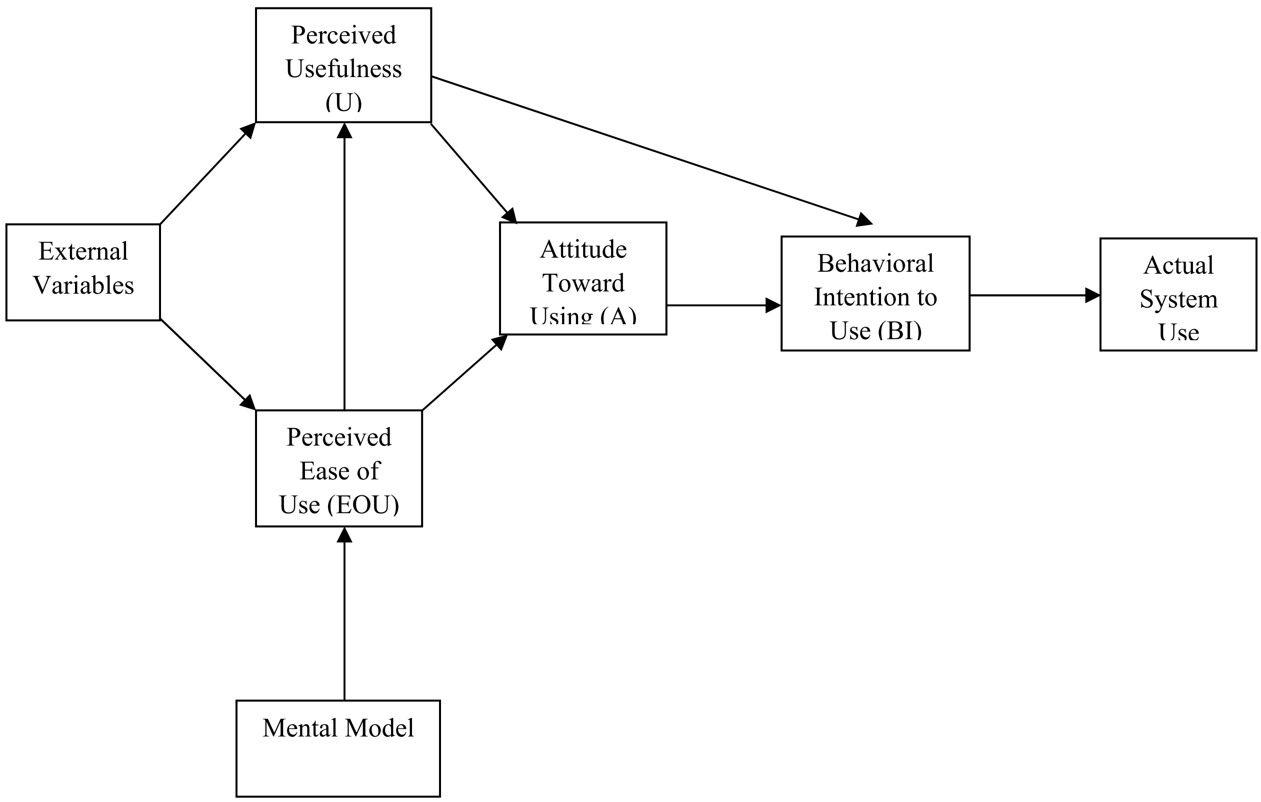
Based on evidence provided by the mental model literature, the following revised model is proposed (Figure 3). In the revised model, the original TAM is extended to include mental models. For simplifying purposes, the original model is used as the basis for my revised model. Venkatesh and Davis (2000) do propose an extension of the Technology Acceptance Model, namely, TAM2, which adds several additional items, including subjective norm. Legris, Ingham and Collerette (2003), however, cite that this most recent version of the TAM still only accounts for about 40% of users' acceptance behaviors, suggesting that the TAM is missing significant factors. Thus, for this paper, the original TAM is used.

Specifically, it is posited that a user's mental model of the computer system affects their perceived ease of use. That is, it is expected that a user's knowledge of how a system works will impact their perceived ease of use of the system. Referring back to Norman's (1983) distinction, a mental model represents a user's understanding of how the system works.

EMPIRICAL TESTING

To operationalize this new construct, users could be provided with a conceptual model of the system. In turn, with the knowledge of how the system works, users can create a more useful mental model of the system, which should make it easier for them to use. In other words, users' greater understanding of the system should positively affect their perceived ease of use, which should positively affect their actual system use.

Figure 3: Revised Model



Intuitively, it makes sense that including mental models can improve the predictive power of the original TAM. After all, Caldeira and Ward (2003) report that a contributing factor for successful IT adoption in small businesses is IS/IT training (132). Similarly, in interviews with small business owners and managers, Mirchandani and Motwani (2001) note that employees' knowledge of computers was a significant factor in whether they adopted electronic commerce technology. In other words, users are more likely to adopt a particular technology when they understand it. According to Bayman and Mayer (1984), one way to aid this understanding is to provide users with a conceptual model of the system.

To test the above revised model, 132 subjects were provided with two case scenarios, both which included a decision aid technology. In both cases, subjects worked through the given task where they had to assess fraud risk for a fictitious company. On the first case, they also had the requirement that they must use the decision aid. Effectively, this first case served as training on the decision aid. It also served to help familiarize them with the case layout and the assigned task.

Subjects then completed the second case with the option to use the decision aid. In both cases, subjects were provided with a conceptual model of the decision aid. Subjects also completed questionnaires after completing each case. The questionnaires were used to collect demographic data, as well as perceived ease of use (EOU) with respect to the decision aid and intent to use the aid (INTENT).

For both EOU and INTENT, the scales were self-reported on a 6-point Likert scale from "Strongly Disagree" to "Strongly Agree." Further, for analysis purposes, summated scales were created for EOU and INTENT, and reliability analysis was performed on both scales. For EOU and INTENT, the Cronbach's alpha coefficients are 0.73 and 0.87, respectively, suggesting that both scales are internally consistent.

A simple average of the responses for EOU was 4.8, meaning that on average, subjects agreed that the decision aid was easy to use. More importantly, the data suggests that as a result of the conceptual model provided to subjects, they found the aid easier to use.

Additionally, a simple linear regression was performed to determine if EOU predicts INTENT. Results of this regression were significant ($t = 3.673, p < 0.001$). In other words, the results suggest that subjects were more likely to use the decision aid if they found it easy to use.

Finally, it is important to note that INTENT serves as a good proxy for actual usage. Over 90% of the subjects actually chose to use the decision aid on the second case. Another simple regression was performed to determine if INTENT predicts actual usage. Results of this regression were significant ($t = 2.975, p < 0.01$). In other words, the results suggest that intent to use generally translates to actual usage.

DISCUSSION AND LIMITATIONS

Per the revised model, it is expected that users' mental models of the system affect their perceived ease of use, which, in turn, affects their intent to use the system. Specifically, users' mental models are operationalized as providing a conceptual model of the system. Empirical testing was performed to test this model. Results suggest that subjects found the decision aid easier to use, and accordingly, were more likely to use the decision aid.

The results of the current study have important implications for studying IT adoption in small businesses. First of all, the results continue to support the link between perceived ease of use (EOU) and intent to use (INTENT) a particular technology. Specifically, users are more likely to use the technology if it's easy to use. In a small business environment, this conclusion is particularly important given the significant cost associated with implementing most technologies. Second, and most importantly, the results suggest that providing a conceptual model of the system makes the system appear easier to use because users gain a better understanding of the system. Again, this conclusion is especially important for small businesses as it ultimately increases the likelihood of successfully adopting a technology.

Despite the encouraging results, there are still several limitations to consider. First, the generalizability of the results is limited since the current study greatly simplified the research setting to include only those variables of interest. Along similar lines, it is important to note that the adjusted R-square of the model (i.e., INTENT regressed on EOU) is fairly low (9%), suggesting that other important factors are missing. Future research should seek to uncover additional factors, as well as test the significance of other factors already in the revised model (e.g., perceived usefulness). Finally, there is the potential for measurement error since both EOU and INTENT are self-reported measures. While the use of multi-item scales somewhat mitigates this likelihood, it is still possible for measurement error to occur.

Overall, the present study adds to the TAM literature by extending the original TAM model. Specifically, the addition of mental models enriches the original TAM model, and theoretically can be applied across a variety of contexts. Finally, the study adds to the small business literature by offering a model that contributes to our knowledge of the factors that lead to successful IT adoption in a small business environment.

REFERENCES

Al-Gahtani, S. (2001). The applicability of TAM outside North America: An empirical test in the United Kingdom. *Information Resources Management Journal 14*(3), 37-46.

Bayman, P. & R.E. Mayer (1984). Instructional manipulation of users' mental models for electronic calculators. *International Journal of Man-Machine Studies 20*(2), 189-199.

Brandt, D.S. (2001). Information technology literacy: Task knowledge and mental models. *Library Trends* 50 (1), 73-86.

Caldeira, M.M. and J.M. Ward (2003). Using resource-based theory to interpret the successful adoption and use of information systems and technology in manufacturing small and medium-sized enterprises. *European Journal of Information Systems 12*(2), 127-141.

Chatzoglou, P.D., E. Vraimaki, A. Diamantidis, and L. Sarigiannidis (2010). Computer acceptance in Greek SME's. *Journal of Small Business and Enterprise Development 17*(1), 78-100.

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

Davis, F.D., R.P. Bagozzi, and P.R. Warshaw (1989). User acceptance of computer technology: A comparison of two theoretical models. *Management Science 35*(8), 982-1003.

Dembla, P., P. Palvia, and B. Krishnan (2007). Understanding the adoption of web-enabled transaction processing by small businesses. *Journal of Electronic Commerce Research 8*(1), 1-17.

Douglas, S.A. (1982). Learning to text edit: semantics in procedural skill acquisition. Unpublished doctoral dissertation, Stanford University.

Fishbein, M. and I. Ajzen (1975). *Belief, attitude, intention, and behavior*. Reading, MA: Addison-Wesley Publishing.

Gentner, D. and D.R. Gentner (1983). Flowing waters or teeming crowds: mental models of electricity. In D.Gentner & A.L. Stevens (Eds.), *Mental Models* (pp. 99-129). Hillsdale, NJ: Lawrence Erlbaum Associates.

Hayes, T. (2008). An examination of the factors that influence an auditor's decision to use a decision aid in their assessment of management fraud. *International Journal of Business, Accounting, and Finance 2*(1), 67-82.

Legris, P., J. Ingham, and P. Collerette (2003). Why do people use information technology? A critical review of the technology acceptance model. *Information and Management 40*(3), 191-204.

Mayer, R.E. (1981). The Psychology of how novices learn computer programming. *ACM Computing Surveys 13* (1), 587-605.

Mirchandani, D.A. and Motwani, J. (2001). Understanding small business electronic commerce adoption: An empirical analysis. *The Journal of Computer Information Systems 41*(3), 70-73.

Norman, D.A. (1983). Some observations on mental models. In D. Gentner & A.L. Stevens (Eds.), *Mental Models* (pp. 7-14). Hillsdale, NJ: Lawrence Erlbaum Associates.

Riemenschneider, C.K., D.A. Harrison, and P.P. Mykytyn, Jr. (2003). Understanding IT adoption decisions in small business: integrating current theories. *Information & Management 40*(4), 269-284.

Staggers, N. and A.F. Norcio (1993). Mental models: Concepts for human-computer interaction research. *International Journal of Man-Machine Studies 38*(4), 587-605.

Thong, J., C. Yap, and K. Raman (1996). Top management support, external expertise and information systems implementation in small businesses. *Information Systems Research 7*(2), 248-267.

U.S. Small Business Administration (2009). *The small business economy: A report to the President.* Washington, DC: U.S. Government Printing Office.

Venkatesh, V. and F.D. Davis (2000). A theoretical extension of the technology acceptance model: Four longitudinal field studies. *Management Science 46*(2), 186-204.

Young, R.M. (1981). The machine inside the machine: users' models of pocket calculators. *International Journal of Man-Machine Studies 15*(1), 51-85.

TESTING A MODERATOR-TYPE RESEARCH MODEL ON THE USE OF HIGH SPEED INTERNET

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ABSTRACT

Telecommunications industry is continually in a shift of change, alimented by technological innovation and consumers' demand for always better and faster communication tools. High speed Internet is now an integral part of everyday life of more than a billion people. And, as the tendency is showing up, its use will be still increasing in the future. Thus, this technology has and will continue to have major social and economic impacts. Individual adoption of technology has been studied extensively in the workplace, but far less attention has been paid to adoption of technology in household (Brown & Venkatesh, 2005). So, few studies have been conducted until now to verify satisfaction of household people using high speed Internet. The aim of this study is then to investigate the determining factors in satisfaction of using high speed Internet by people in household. 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 personal computer in household by American people, this study examines the determining factors in satisfaction of using high speed Internet in household by Canadian people. The methodology followed to conduct the study was the telephone survey research. Data were collected from 322 randomly selected Atlantic Canadian people using high speed Internet at home. Data analysis was performed using the structural equation modeling software Partial Least Squares (PLS). The results revealed that near from half of the variables examined in the study showed to be determining factors in satisfaction of using high speed Internet by people in household.

INTRODUCTION AND BACKGROUND FOR THE STUDY

The vast technological possibilities of the Internet are at the basis of the fast progress of the information society (Al-Omoush & Shaqrah, 2010). It has become one of the most important means of new forms of cooperation and competition in the various subsystems of society (Al-Omoush & Shaqrah, 2010). Anderson (2008) argues that Internet has a great influence on people's connections to friends, families, and their communities, on the social system of formal and informal support, and on the working of groups and teams. It is also the valuable instrument of scientific, social, marketing researches, and business development (Al-Omoush & Shaqrah, 2010). In addition, the Internet, as an information and entertainment technology, affects education, government, publishing, retail industry, banking, broadcast services, health care delivery, and so on (Al-Omoush & Shaqrah, 2010). So, the scope of the Internet is now worldwide and in all sectors of the society, and then forces to deliver this essential resource to people in households. In order to provide the reader with a good overall view of the actual Internet population, we have regrouped in Table 1 the different generations (as conventionalized by Strauss and Howe's book: *Generations: The History of America's Future, 1584 to 2069*) and the percentages of adult both total and online.

Table 1: Generations Explained
(adapted from Jones & Fox, 2009, p. 1)

Generation Names	*Birth Years, Ages in 2009*	*% of Total Adult Population*	*% of Internet-Using Population*
Gen Y (millennials)	Born 1977-1990, Ages 18-32	26	30
Gen X	Born 1965-1976, Ages 33-44	20	23
Younger Boomers	Born 1955-1964, Ages 45-54	20	22
Older Boomers	Born 1946-1954, Ages 55-63	13	13
Silent Generation	Born 1937-1945, Ages 64-72	9	7
G.I. Generation	Born -1936, Age 73+	9	4

Source: Pew Research Center's Internet & American Life Project December 2008 survey. N = 2,253 total adults, and margin of error is ± 2%. N = 1,650 total Internet users, and margin of error is ± 3%.

As shown in Table 1, "Contrary to the image of Generation Y as the 'Net Generation,' Internet users in their twenties do not dominate every aspect of online life. Generation X is the most likely group to bank, shop, and look for health information online. Boomers are just as likely as Generation Y to make travel reservations online. And even Silent Generation Internet users are competitive when it comes to e-mail (although teens might point out that this is proof that e-mail is for old people). The Web continues to be populated largely by younger generations, as more than half of the adult Internet population is between 18 and 44 years old. But larger percentages of older generations are online now than in the past and they are doing more activities online, according to the Pew Research Center's Internet & American Life Project surveys taken from 2006-2008." (Jones & Fox, 2009, p. 1)

As the Internet population is continually growing since its infancy, the need for always faster and performing telecommunications networks allowing people to communicate and to perform their daily activities at a satisfying pace has become an everyday concern for all the countries, hence the apparition of high speed Internet in the middle of the 1990s. For example, for more than a decade, the Government of Canada has been developing strategies to enable Canadians to become participants in the information society (Government of Canada, 1999; Government Online Advisory Panel, 2003; quoted in Middleton & Ellison, 2006, p. 1). As part of this strategy, it was recommended that broadband Internet access be made available to all Canadian households (National Broadband Task Force, 2001; quoted in Middleton & Ellison, 2006, pp. 1-2). There are still many not served and underserved areas in the country (CRACIN, 2005), and the Telecommunications Policy Review Panel has urged the federal government to "reaffirm its commitment to maintaining Canada's global broadband leadership and to ensuring that broadband access is available everywhere in the country" (Telecommunications Policy Review Panel, 2006, p. 8-5; quoted in Middleton & Ellison, 2006, p. 2). Similarly, as a public issue, broadband has taken on a higher profile in recent months because of President Obama's decision to include funding for broadband in the American Recovery and Reinvestment Act (ARRA); also ARRA included $7.2 billion for broadband with the goal of accelerating the deployment of broadband Internet access in the United States (Horrigan, 2009). These are just two examples here of how much all of the countries are putting a strong emphasis on strategies capable of promoting the acceleration of the deployment of high speed Internet everywhere in the world. As a result, the number of households with a broadband Internet connection continues to grow with one in five households worldwide expected to have a fixed broadband connection by the end of 2009, according to Gartner Research (Digital Home, 2009).

In 2009, Canada ranked fifth in broadband penetration. In fact, leading the high speed Internet race at the beginning of 2009 was South Korea at 86%, followed by the Netherlands (80%), Denmark (75%), and Hong Kong (72%), followed by Canada and Switzerland (69%). Rounding out the top ten were Norway (67%), New Zealand (65%), France, Singapore and the UK (62%). The United States ranked 14th at 60%. Overall, in 2009, approximately 21 countries had high speed Internet connections in at least 50 percent of homes. (Digital Home, 2009)

But, what is high speed Internet?

According to Gill (2010), ever wonder what a company means when it says its Internet service is "high speed"? Then check out Table 2 that documents the plethora of technologies that the Federal Communications Commission (FCC) counts as "broadband" -- be warned, speeds can vary by as much as 2,000 percent (for example, regarding Canada, Dunn (2010) argues that high speed Internet access is expensive and slow)! In short, "broadband" is defined by the FCC as anything other than "dial up" -- and "high speed" has no commonly-agreed-to definition (Gill, 2010). So, in this paper, when we talk about "high speed" Internet or "broadband", we then consider the two as the same telecommunications technology which is faster than "dial up".

Table 2: Main High Speed or Broadband Technologies
(adapted from Gill, 2010, pp. 3-4)

Technologies	*Speeds*[1]
Cable	Basic: 4 Mbps to 6 Mbps High End: 12 Mbps to 16 Mbps and faster
DSL	Basic: 768 Kbps to 1.5 Mbps High End: 3 Mbps to 7 Mbps
Fiber Optic Cable	15 Mbps to 25 Mbps
Mobile -- EDGE	Up to 58 Kbps, average 22 Kbps

Table 2: Main High Speed or Broadband Technologies (adapted from Gill, 2010, pp. 3-4)	
Technologies	*Speeds*[1]
Mobile -- 3G	AT&T: Download: 700 Kbps to 1.7 Mbps; Upload: 500 Kbps to 1.2 Mbps Sprint: Download: 600 Kbps to 1.4 Mbps Verizon: 600 Kbps to 1.4 Mbps
Mobile -- 4G	Download: 3 to 6 Mbps
Satellite	10 to 20 Kbps
WiMax (like Clear)	Download: 3 to 6 Mbps
South Korea	1 Gbps (2012)
Japan	Average: 93.6 Mbps (2007)
France	Average: 44.1 Mbps (2007)

[1]One kilobit per second (Kbps) is 1,000 bits per second (bps). One megabit per second (Mbps) is 1,000 Kbps or 1,000,000 bps. One gigabit per second (Gbps) is 1,000 Mbps or 1,000,000 Kbps or 1,000,000,000 bps.

What are the anticipated benefits of high speed Internet?

Here we provide the reader with only a brief overview of the anticipated benefits of high speed Internet given that the studies presented in Table 3 are further putting in evidence some benefits. Thus, we describe in the next paragraphs three relevant examples of benefits that high speed Internet can bring: one at the environmental level, one at the social level, and one at the economic level.

First, a study realized by Fuhr and Pociask released in October 2007 by the American Consumer Institute praises the benefic impact that a widely spread use of broadband could have on the environment by cutting greenhouse gas emissions. The study focuses on the different behaviors that the use of high speed Internet allows, such as buying online, telecommuting, e-materializing, teleconferencing, videoconferencing, as well as distance learning, and converts their benefits into saving of greenhouse gas emissions by mainly cutting on energy. According to Fuhr and Pociask (2007; quoted in Labriet-Gross, 2007), using high speed Internet mainly influences the amount of travel, space and material needed when you buy, work or lean based on rather simple findings. "Indeed, instead of going to five or 6 stores to find who has a product or who has the best price, you can just search on the Internet and buy online, so it cuts back on the pollution linked to the commute", explain these authors. As for the supply chain, it decreases the inventory, which means less storage facilities, so less need for heat, air conditioning, and lighting. For instance, Dell has increased its sales by 36 times, while its facilities space has been reduced by 4. Overall, e-commerce already cuts 37.5 million tons of $CO2$ emissions (and only in business to business (B2B) and business to consumers (B2C) transactions), and could save 206.3 million tons in 2017, argue Fuhr and Pociask (2007; quoted in Labriet-Gross, 2007).

Varon (2010) relates the experience of Case Western Reserve University who launched the University Circle Innovation Zone, a large project deploying gigabit fiber optic connections to residents of Cleveland's poorest neighborhoods. Beginning with 104 homes, local institutions, including hospitals, schools, electric utilities, and public safety agencies, will use the network to deliver cutting edge services to residents. Over the next 18 months, Case Western researchers will study changes in residents' health and other indicators of their standard of living. One project will use videoconferencing technology provided by LifeSize to enable residents with chronic conditions such as diabetes to consult with healthcare providers over high definition video. Patients will also be given devices that automatically monitor their health and transmit data to medical professionals. Broadband access could enable residents to take better care of them when they cannot visit their doctors. Other projects would provide science and math… materials to students, deliver video feeds to police, and collect data to help residents manage energy usage. Case Western's technology and service provider partners are financing this social initiative.

And, a study conducted by Orazem (2005) measuring the impact of high speed Internet access on local economic growth suggests that this one increases growth in earnings per worker, aggregate earnings and the number of firms, but it lowers the rate of growth of employment. All of these are consistent with the presumption that high speed Internet access can lower firm costs, improve information flows with suppliers and consumers, and, at the same time, lower the need for employees specializing in sales or procurement. And all of these effects were larger in less density populated areas, then suggesting that rural areas do benefit disproportionately from high speed Internet access. A more recent study made by Majumdar (2008) is consistent with Orazem's (2005) findings concerning earnings per worker and employment, that is, he found that broadband diffusion within and between the firms over time has a positive and significant impact on wage levels, but its impact on employment is negative.

On the other hand, what are the main barriers to high speed Internet adoption?

According to the Pew Internet & American Life Project (see Horrigan, 2009), the factors positively correlated with home broadband adoption (in order of importance) are: income (household income greater than $75,000 annually); having college degree or more; parent of minor child in household); married or living with partner; and full-time employee. As for the factors negatively correlated with home broadband adoption (in order of importance), they are: having less than a high school degree; senior individual (aged of 65 or over); living in rural America; having a high school degree; and being African American (non-Hispanic).

Telecommunications industry is continually in a shift of change, alimented by technological innovation and consumers' demand for always better and faster communication tools. High speed Internet is now an integral part of everyday life of more than a billion people. And, as the tendency is showing up, its use will be still increasing in the future. Thus, this technology has and will continue to have major social and economic impacts. Individual adoption of technology has been studied extensively in the workplace, but far less attention has been paid to adoption of technology in household (Brown & Venkatesh, 2005). So, few studies have been conducted until now to verify satisfaction of household people using high speed Internet. It is therefore crucial to more deeply examine the determining factors in satisfaction of using high speed Internet by people in household. This is the aim of the present study. The related literature on the actual research area of high speed Internet is summarized in Table 3.

As we can see in the summary of literature related to high speed Internet presented in Table 3, very few studies until now examined the determining factors in satisfaction of using high speed Internet by people in household. Thus, the present study brings an important contribution to fill this gap given it allows a better understanding of the impacts of high speed Internet usage in people's everyday life. It focuses on the following research question: What are the determining factors in satisfaction of using high speed Internet by people in household?

Table 3: Related Literature Survey

Research Area	*References*
High speed Internet social impact and economic growth.	Orazem (2005) Selouani & Hamam (2007) Anderson (2008)
High speed Internet and wages and employment.	Majumdar (2008)
High speed Internet and health.	Dumitru et al. (2007) Rains (2008)
High speed Internet and regulation.	Cambini & Jiang (2009) Howard & Mahazeri (2009)
High speed Internet migration, implementation, and support.	Ida & Sakahira (2008) Platt et al. (2010)
High speed Internet adoption and use.	Perry et al. (1998) Matthews & Schrum (2003) Middleton & Ellison (2006) Dumitru et al. (2007) Windhausen Jr. (2008) Horrigan (2009) Howard & Mahazeri (2009) Al-Omoush & Shaqrah (2010) Helsper (2010) Rosston et al. (2010)
High speed Internet (e.g., ISP) user satisfaction.	Tao et al. (2009)

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 development of the study is presented; second, the methodology followed to conduct the study is described; finally, the results of the study are reported and discussed.

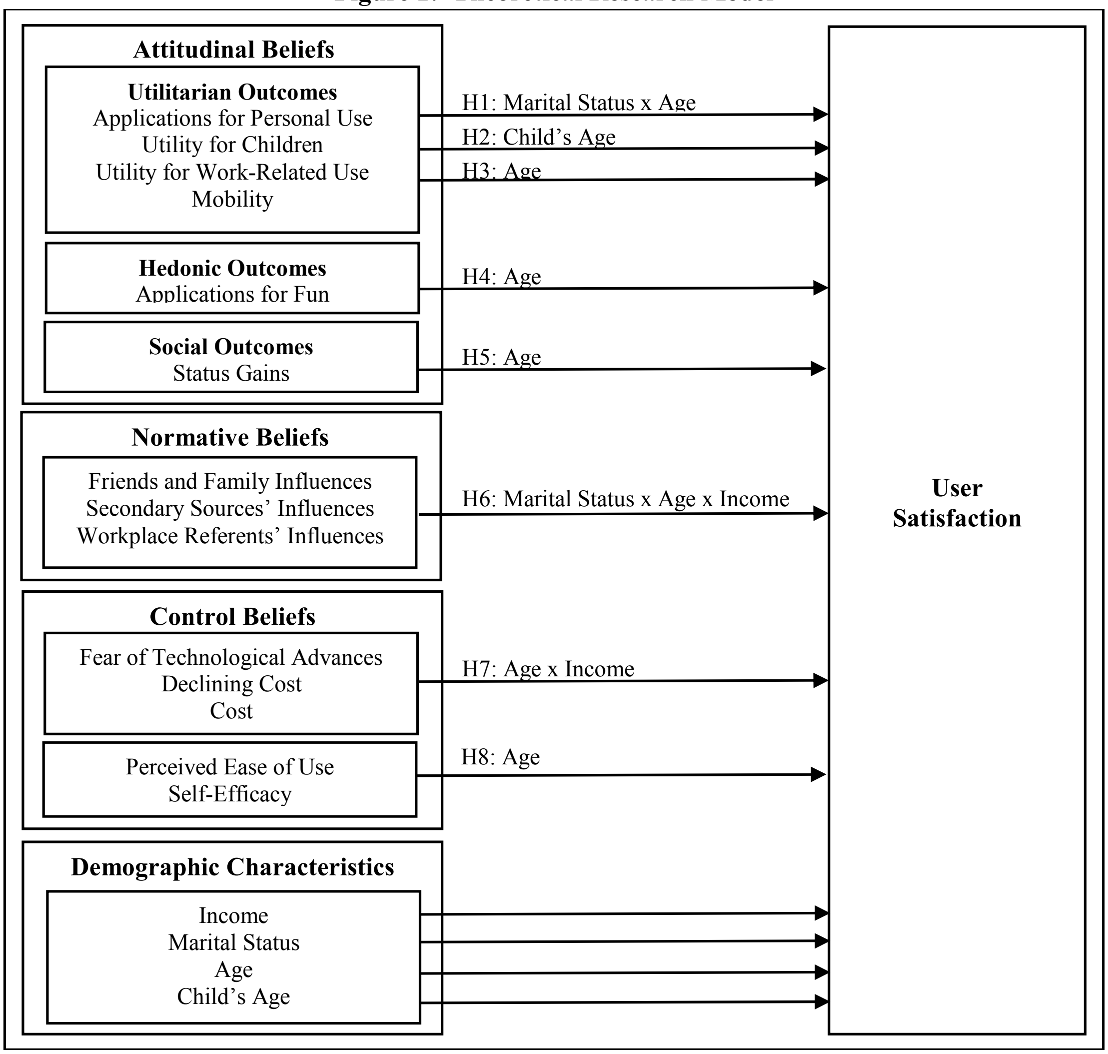
THEORETICAL DEVELOPMENT

This study is based on the theoretical foundations developed by Venkatesh and Brown (2001) to investigate the factors driving personal computer (PC) adoption in American homes as well as those developed by Brown and Venkatesh (2005) in order to verify the determining factors in intention to adopt a PC 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. And Brown et al. (2006) tested the same integrated model in the context of PC use. As pointed out by Brown et al. (2006), even though the technology of interest in MATH is PC, the model is expected to generalize to other information technology (IT) products and systems in the household context. Also, with the exception of behavioral intention (we included user satisfaction instead of behavioral intention given people investigated in this study already have high speed Internet access), all the variables proposed and tested by Brown and Venkatesh (2005) are used in this study. And we added a new variable, mobility, in order to verify whether or not it is a factor of satisfaction of household people using high speed Internet. The resulting theoretical research model is depicted in Figure 1.

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 *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 PC adoption (household high speed Internet 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 high speed Internet by people in household). All of the variables integrated in the theoretical research model depicted in Figure 1 are defined in Table 4.

We can see in Table 4 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 PC 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 definition of the new independent variable that we added to the model is from our own. In fact, we defined this variable in accordance with which we wanted to measure regarding mobility before developing and validating items that measure the variable on the basis of the definition formulated.

Figure 1: Theoretical Research Model



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 high speed Internet at home.

H2: Child's age will moderate the relationship between utility for children and satisfaction of using high speed Internet at home.

H3: Age will moderate the relationship between utility for work-related use and satisfaction of using high speed Internet at home.

H4: Age will moderate the relationship between applications for fun and satisfaction of using high speed Internet at home.

Table 4: Variables and Definitions

Beliefs and Characteristics	*Variables*	*Definitions*
Dependent Variable	User Satisfaction	According to Cyert and March (1963, p. 126), an information system or information technology which meets the needs of its user will reinforce satisfaction with that system or technology. If the system or technology does not provide the needed information or service, the user will become dissatisfied and look elsewhere.
Attitudinal Beliefs (independent variables)	Applications for Personal Use	The extent to which using high speed Internet enhances the effectiveness of household activities (Venkatesh & Brown, 2001).
	Utility for Children	The extent to which using high speed Internet enhances the children's effectiveness in their activities (Venkatesh & Brown, 2001).
	Utility for Work-Related Use	The extent to which using high speed Internet enhances the effectiveness of performing work-related activities (Venkatesh & Brown, 2001).
	Mobility	The extent to which high speed Internet allows using only this technology to perform all personal and professional activities.
	Applications for Fun	The pleasure derived from high speed Internet use (Venkatesh & Brown, 2001). These are specific to high speed Internet usage, rather than general traits (Brown & Venkatesh, 2005; see Webster & Martocchio, 1992, 1993).
	Status Gains	The increase in prestige that coincides with the purchase of high speed Internet access for home use (Venkatesh & Brown, 2001).
Normative Beliefs (independent variables)	Friends and Family Influences	"The extent to which the members of a social network influence one another's behavior" (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 behavior (Venkatesh & Brown, 2001).
	Workplace Referents' Influences	The extent to which coworkers influence behavior (Brown & Venkatesh, 2005; see Taylor & Todd, 1995).

Table 4: Variables and Definitions		
Beliefs and Characteristics	*Variables*	*Definitions*
Control Beliefs (independent variables)	Fear of Technological Advances	The extent to which rapidly changing technology is associated with fear of obsolescence or apprehension regarding high speed Internet access purchase (Venkatesh & Brown, 2001).
	Declining Cost	The extent to which the cost of high speed Internet access is decreasing in such a way that it inhibits adoption (Venkatesh & Brown, 2001).
	Cost	The extent to which the current cost of high speed Internet access is too high (Venkatesh & Brown, 2001).
	Perceived Ease of Use	The degree to which using high speed Internet is free from effort (Davis, 1989; see also Venkatesh & Brown, 2001).
	Self-Efficacy (or Requisite Knowledge)	The individual's belief that he/she has the knowledge necessary to use high speed Internet. This is closely tied to computer self-efficacy (Compeau & Higgins, 1995a, 1995b; see also Venkatesh & Brown, 2001).
Life Cycle Characteristics (moderator variables)	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.

H5: Age will moderate the relationship between status gains and satisfaction of using high speed Internet 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 high speed Internet 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 high speed Internet 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 high speed Internet at home.

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

METHODOLOGY

The study was designed to gather information concerning high speed Internet satisfaction in Atlantic Canadian households. Indeed, the focus of the study is on individuals who have high speed Internet access at home. 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 empirically validated by Brown and Venkatesh (2005) to which we added two new scales, the first one measuring another dimension in satisfaction of using high speed Internet by people in household, that is, 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, few 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 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 variable 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 from a large area in Atlantic Canada, which have high speed Internet access. To do that, 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, to get the more diversified sample as possible (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 that end, the phone number of each respondent was put in a box for the drawing. Following this data collection process, 322 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 (322 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. First, we begin to present some characteristics of the participants. Then we validate the PLS model developed to test the research hypotheses. Finally, we describe the results got from PLS analyses to test the research hypotheses.

Participants

The participants in this study were relatively aged, with a mean of 40 years and a standard deviation of 13.7 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 (62.7%). Near from 80% of the participants were married (52.1%) or single (26.8%). The gross yearly income of the respondents in the study was in the range of $0 to $60,000. Indeed, 80.9% of the respondents were winning between $0 and $60,000, and, from this percentage, 47.3% were winning between $30,000 and $60,000. And 5.3% of the respondents were winning $100,000 or over. Concerning the level of education, 20.3% of the participants in the study got a high-school diploma, 28.3% got a college degree, 37.3% completed a baccalaureate, and 10.3% got a master. Only 2.9% of the participants completed a doctorate, which is relatively consistent with the whole population in general. Finally, the respondents in our study were mainly full-time employees (46.8%), part-time employees (14.6%), retired people (13.3%), self employed (8.9%), unemployed (7.6%), and students (5.4%).

Validation of the PLS Model to Test Hypotheses

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

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

And to get composite reliability indexes and average variance extracted (AVE) in order to satisfy the second criterion of discriminant validity and to verify internal consistency of the variables, we used PLS bootstrap resampling procedure with an iteration of 100 sub-sample extracted from the initial sample (322 Atlantic Canadian people). The results are presented in Table 5.

As shown in Table 5, 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 5 that PLS analysis showed high composite reliability indexes for all variables of the theoretical research model. The variables have therefore a high internal consistency, with composite reliability indexes ranging from 0.74 to 0.99.

Hypothesis Testing

First, to get the significant variables in the study and the percentage of variance explained (R^2 coefficient) by all the variables of the theoretical research model, we developed a PLS model similar to those of Fillion (2005), Fillion and Le Dinh (2008), Fillion et al. (2010a), Fillion and Booto Ekionea (2010b), and Yoo and Alavi (2001). And to ensure the stability of the model, we used the PLS bootstrap resampling procedure with an iteration of 100 sub-sample extracted from the initial sample (322 Atlantic Canadian people). The PLS model is depicted in Figure 2.

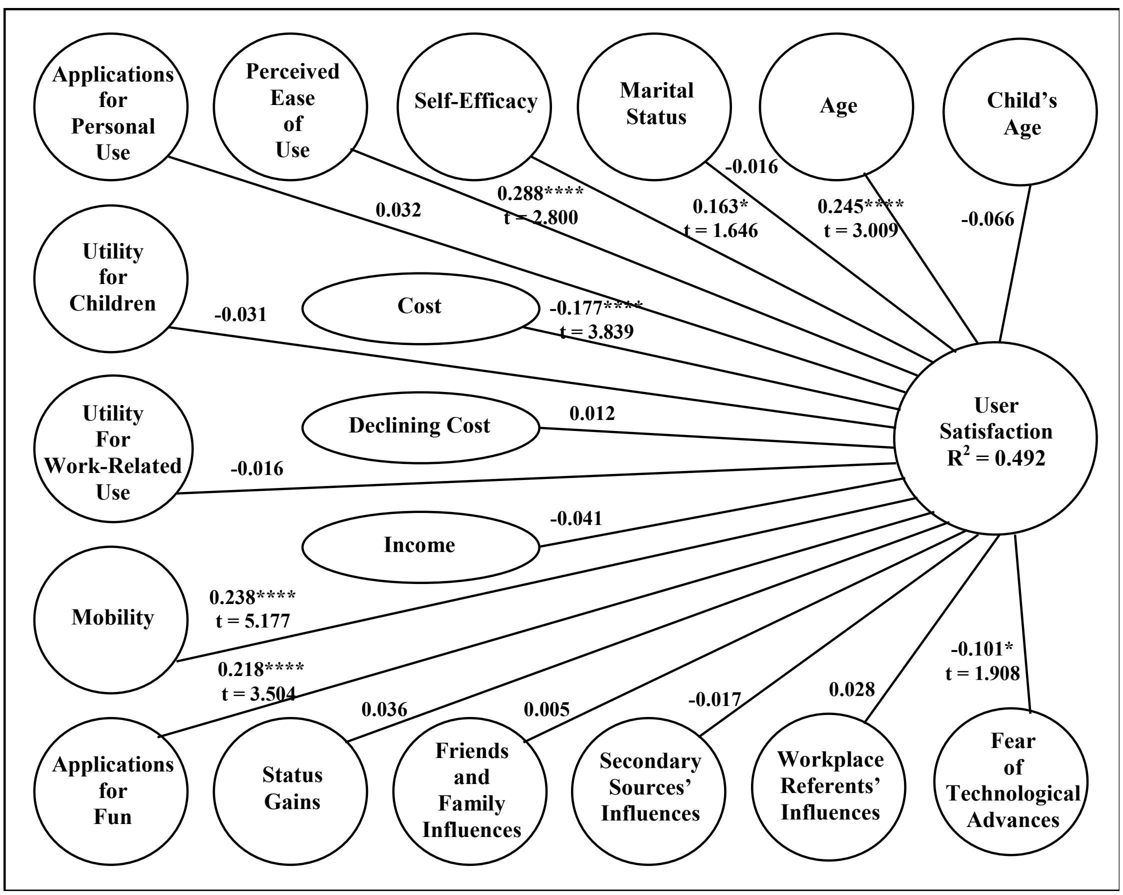
Table 5: Means, Standard Deviations, Composite Reliability Indexes, Correlations, and Average Variance Extracted of Variables

Variables	*M*	*SD*	*Relia-bility Index*	*Correlations and Average Variance Extracted*[e]																		
				1	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*	*15*	*16*	*17*	*18*	*19*
1. Applications for Personal Use	5.17	1.87	**0.82**	**0.78**																		
2. Utility fo Children	3.07	3.00	**0.99**	.13	**0.98**																	
3. Utility for Work-Related Use	4.47	2.63	**0.89**	.21	.12	**0.85**																
4. Mobility	4.70	2.63	**0.89**	.11	.17	.28	**0.85**															
5. Applications For Fun	4.83	1.95	**0.86**	.29	.09	-.02	.30	**0.78**														
6. Status Gains	2.88	2.08	**0.94**	.08	.06	.11	.17	.29	**0.92**													
7. Friends and Family Influences	3.75	2.48	**0.93**	.06	.01	.10	.20	.27	.36	**0.87**												
8. Secondary Sources' Influences	3.73	2.20	**0.85**	.12	.09	.05	.20	.37	.26	.39	**0.81**											
9. Workplace Referents' Influences	3.15	3.00	**0.91**	.15	.07	.29	.19	.11	.21	.42	.27	**0.92**										
10. Fear of Techno-logical Advances	2.87	2.07	**0.87**	.03	.11	.09	-.04	.01	.13	.16	.11	.06	**0.83**									
11. Declining Cost	3.93	2.07	**0.86**	.16	.08	.20	.22	.13	.16	.14	.10	.15	-.01	**0.83**								
12. Cost	4.77	1.93	**0.74**	-.22	-.07	-.19	-.11	-.11	-.12	-.15	-.12	-.16	.18	-.29	**0.70**							
13. Perceived Ease of Use	5.73	1.45	**0.83**	.30	-.04	.12	.25	.26	.10	.07	.17	.14	-.26	.13	-.23	**0.76**						
14. Self-Efficacy	6.37	1.05	**0.93**	.29	.01	.11	.24	.20	.07	.04	.11	.08	-.25	.13	-.18	.47	**0.90**					
15. Income[a]	NA	NA	**NA**	.10	.25	.13	.01	-.20	-.11	-.10	-.09	.04	-.12	.03	-.06	.04	.05	**NA**				
16. Marital Status[b]	NA	NA	**NA**	-.07	-.29	-.01	.16	.13	.05	.09	.11	.14	-.13	-.12	-.05	.12	.06	-.26	**NA**			
17. Age[c]	40.00	13.70	**NA**	-.05	.08	-.07	-.28	-.22	-.05	-.08	-.18	-.30	.19	-.06	.15	-.22	-.26	.28	-.27	**NA**		
18. Child's Age[d]	14.91	8.89	**NA**	-.06	-.20	-.12	-.20	-.07	-.01	.01	-.08	-.20	.07	-.08	.11	-.13	-.20	-.02	-.05	.34	**NA**	
19. User Satisfaction	5.72	1.38	**0.90**	.28	.06	.13	.38	.39	.18	.15	.17	.11	-.20	.20	-.32	.56	.49	.03	.02	-.08	-.07	**0.77**

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

As we can see in Figure 2, all of the variables of our theoretical research model, used as independent variables, are explaining 49.2% of the variance on the dependant variable user satisfaction. And about half of these variables are significant, that is, they are determining factors in satisfaction of using high speed Internet by people in household. More specifically, the five more significant variables (in order of significance) are mobility (t = 5.177, beta = 0.238, p < 0.001), cost (t = 3.839, beta = -0.177, p < 0.001), applications for fun (t = 3.504, beta = 0.218, p < 0.001), age (t = 3.009, beta = 0.245, p < 0.001), and perceived ease of use (t = 2.800, beta = 0.288, p < 0.001). And two other variables are significant at the level of significance required in this study, that is, p ≤ 0.05. They are fear of technological advances (t = 1.908, beta = -0.101, p < 0.05) as well as self-efficacy (t = 1.646, beta = 0.163, p < 0.05). As shown in Figure 2, our new variable mobility is by far the more significant variable in the global PLS structural model. So, in this study, the fact that high speed Internet allows using only this technology to perform all personal and professional activities is by far the more satisfying factor for Atlantic Canadian people when they choose to get access to high speed Internet from Internet services providers (ISP).

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



*p < 0.05; ****p < 0.001.

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 through 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 in information systems (IS) journals, Carte and Russell (2003) found nine errors frequently committed by researchers when they estimate such an effect, and provided solutions (see their paper for more details). We tried to avoid these nine errors in applying their solutions to test hypotheses 1 through 8. Indeed, among others, in the verification of hypotheses 1 through 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, $\hat{}R^2$ (named delta R^2)) is greater than 0.

For a matter of space, as the test of hypotheses 1 through 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, for each PLS model developed, we used the PLS bootstrap resampling procedure with an iteration of 100 sub-sample extracted from the initial sample (322 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 not significant ($t = 0.882$, beta = -0.181), but there is a substantial change in R^2 ($\hat{}R^2 = 0.006$). So, contrary to our expectations, the moderator variables marital status and age have not an influence on the relationship between applications for personal use and satisfaction of using high speed Internet by people in household. Hypothesis 1 is therefore not supported. The scenario is similar 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 ($t = 0.219$, beta = 0.039) and there is no change in R^2 ($\hat{}R^2 = 0.000$). Also, contrary to what we expected, the moderator variable child's age has not an influence on the relationship between utility for children and satisfaction of using high speed Internet 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 ($t = 1.646$, beta = 0.457, $p < 0.05$) and there is a huge change in R^2 ($\hat{}R^2 = 0.015$). Thus, as we expected, the moderator variable age has an influence on the relationship between utility for work-related use and satisfaction of using high speed Internet by people in household. Hypothesis 3 is therefore supported. The scenario is similar for 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 significant (t = 1.695, beta = -0.334, $p < 0.05$) and there is a huge change in R^2 ($^\wedge R^2 = 0.014$). Thus, as we expected, the moderator variable age has an influence on the relationship between applications for fun and satisfaction of using high speed Internet by people in household. As a result, hypothesis 4 is also supported. And the scenario is still similar regarding 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 significant (t = 1.712, beta = -0.339, $p < 0.05$) and there is a huge change in R^2 ($^\wedge R^2 = 0.011$). Thus, as we expected, the moderator variable age has an influence on the relationship between status gains and satisfaction of using high speed Internet by people in household. Consequently, hypothesis 5 is also supported.

In the case of hypothesis 6a 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 = 0.894, beta = -0.122), but there is a change in R^2 ($^\wedge R^2 = 0.004$). Also, 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 high speed Internet by people in household. Hypothesis 6a is then not supported. The scenario is similar for hypothesis 6b 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 not significant (t = 0.263, beta = 0.041) and there is no change in R^2 ($^\wedge R^2 = 0.000$). Contrary to what we expected, the moderator variables marital status, age, and income have not an influence on the relationship between secondary sources' influences and satisfaction of using high speed Internet by people in household. As a result, hypothesis 6b is not supported. The scenario is also similar concerning hypothesis 6c 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 not significant (t = 0.327, beta = 0.042) and there is no change in R^2 ($^\wedge R^2 = 0.000$). Contrary to our expectations, the moderator variables marital status, age, and income have not an influence on the relationship between workplace referents' influences and satisfaction of using high speed Internet by people in household. Hypothesis 6c is therefore not supported.

As for hypothesis 7a 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 = 0.888, beta = -0.109), but there is a change in R^2 ($^\wedge R^2 = 0.003$). 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 high speed Internet by people in household. Hypothesis 7a is therefore not supported. The scenario is similar for hypothesis 7b 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 = 0.434, beta = 0.068) and there is no change in R^2 ($^\wedge R^2 = 0.000$). Also, contrary to what we expected, the moderator variables age and income have not an influence on the relationship between declining cost and satisfaction of using high speed Internet by people in household. Consequently, hypothesis 7b is not supported. And the scenario is also similar for hypothesis 7c 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 = 0.021, beta = 0.003) and there is no change in R^2 ($^R^2$ = 0.000). Thus, contrary to our expectations, the moderator variables age and income have not an influence on the relationship between cost and satisfaction of using high speed Internet by people in household. As a result, hypothesis 7c is not supported.

Finally, concerning hypothesis 8a 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 = 0.801, beta = -0.324), but there is a change in R^2 ($^R^2$ = 0.003). 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 high speed Internet by people in household. As a result, hypothesis 8a is not supported. The scenario is different for hypothesis 8b 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 = 2.412, beta = -1.286, $p < 0.01$) and there is a huge change in R^2 ($^R^2$ = 0.033). So, as we expected, the moderator variable age has an influence on the relationship between self-efficacy and satisfaction of using high speed Internet by people in household. Consequently, hypothesis 8b is supported. In order to provide the reader with an overall view of the test of hypotheses, Table 6 presents a summary.

In summary, as shown in Table 6, four hypotheses have been supported in our study, that is, H3, H4, H5, and H8b. Thus, the moderator variable age had several moderating effects in this study. As for moderator variables marital status, income, and child's age, these ones had not a significant moderating effect on the relations between the independent and dependent variables involved. Hence hypotheses H1, H2, H6a, H6b, H6c, H7a, H7b, and H7c were not supported. And the moderator variable age had not a significant moderating effect on the relation between perceived ease of use and satisfaction of using high speed Internet at home. Hence hypothesis H8a was not supported.

Table 6: Summary of the Test of Hypotheses

Hypotheses	*Results*	*Software (beta sig.)*
H1- Marital status and age will moderate the relationship between applications for personal use and satisfaction of using high speed Internet at home.	Not supported	PLS (-0.181)
H2- Child's age will moderate the relationship between utility for children and satisfaction of using high speed Internet at home.	Not supported	PLS (0.039)
H3- Age will moderate the relationship between utility for work-related use and satisfaction of using high speed Internet at home.	Supported	PLS (0.457*)
H4- Age will moderate the relationship between applications for fun and satisfaction of using high speed Internet at home.	Supported	PLS (-0.334*)

Table 6: Summary of the Test of Hypotheses		
Hypotheses	*Results*	*Software (beta sig.)*
H5- Age will moderate the relationship between status gains and satisfaction of using high speed Internet at home.	Supported	PLS (-0.339*)
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 high speed Internet at home.	a- Not supported b- Not supported c- Not supported	PLS (-0.122) PLS (0.041) PLS (0.042)
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 high speed Internet at home.	a- Not supported b- Not supported c- Not supported	PLS (-0.109) PLS (0.068) PLS (0.003)
H8- Age will moderate the relationship between the internal control beliefs ((a) perceived ease of use; and (b) self-efficacy) and satisfaction of using high speed Internet at home.	a- Not supported b- Supported	PLS (-0.324) PLS (-1.286**)
*p < 0.05; **p < 0.01.		

In the next and last section of the paper, we discuss about the more important findings of the study, the theoretical and practical implications, the limitations, and the future directions.

DISCUSSION AND CONCLUSIONS

This last section is devoted to a discussion about the findings of the study and some conclusions. First, 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 7).

As shown in Table 7 (and Figure 2), the eighteen independent variables examined in the study explained 49.2 percent (R^2 = 0.492) of the variance in satisfaction of using high speed Internet at home. And we can also see in Table 7 that the seven variables who showed to be significant (see also the significant beta path coefficients in Figure 2), that is, mobility, cost, applications for fun, age, perceived ease of use, fear of technological advances, and self-efficacy explained alone 45.9 percent of the variance in satisfaction of using high speed Internet at home. Thus, these seven variables are assuredly very important factors to take into account in future studies on high speed Internet and on the part of high speed Internet providers, and more particularly self-efficacy and perceived ease of use which explained alone 33 percent of this variance (see Table 7). It is very interesting and surprising here to see that the new variable that we added to the Brown and Venkatesh's (2005) theoretical research model, that is mobility, showed to be the more significant ($t = 5.177$, beta = 0.238, $p < 0.001$; see Table 7) in satisfaction of using high speed Internet by people in household. Indeed, the present study showed that people are, to some extent, using high speed Internet for a matter of mobility (e.g., high speed

Internet provides them with the possibility to use only this technology to perform all their personal and professional activities). So, here is a new variable that we can now assuredly include in the integrated research model of MATH and household life cycle characteristics suggested by Brown and Venkatesh (2005) as well as Brown et al. (2006) to test in future studies. In fact, we included this new variable mobility in the integrated model of MATH and household life cycle characteristics in several different studies (see Fillion & Berthelot, 2007; Fillion & Le Dinh, 2008; Fillion & Booto Ekionea, 2010b) and it always showed a very significant effect on the dependent variables involved. Of course, its inclusion in the integrated model will depend on its relevance to the technologies examined in the studies. For example, mobility can be included in studies on mobile phone, high speed Internet, or PC, but it cannot be integrated in studies on e-government services, e-learning, or course management software. On the practical point of view, this new variable mobility can be included in the sales marketing plan of high speed Internet providers.

Table 7: Beta Path Coefficients, T-Values, and Percentages of Variance Explained of Variables

Variables	*Beta Coefficients*	*t-values (one-tail)*	R^2
Applications for Personal Use	0.032	0.566	0.001
Utility for Children	-0.031	0.729	0.001
Utility for Work-Related Use	-0.016	0.317	0.000
Mobility	0.238****	5.177	0.037
Applications for Fun	0.218****	3.504	0.047
Status Gains	0.036	0.823	0.004
Friends and Family Influences	0.005	0.117	0.004
Secondary Sources' Influences	-0.017	0.380	0.005
Workplace Referents' Influences	0.028	0.588	0.002
Fear of Technological Advances	-0.101*	1.908	0.003
Declining Cost	0.012	0.258	0.005
Cost	-0.177****	3.839	0.038
Perceived Ease of Use	0.288****	2.800	0.081
Self-Efficacy	0.163*	1.646	0.249
Income	-0.041	0.819	0.006
Marital Status	-0.016	0.300	0.000
Age	0.245****	3.009	0.004
Child's Age	-0.066	0.903	0.005

*p < 0.05; ****p < 0.001.

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 PC 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 a new independent variable to the model, that is, mobility. And we also used the household life cycle variables as moderating variables in our research model as did Brown and Venkatesh (2005). Finally, as we investigated the perceptions of people already using high speed Internet at home instead of those having the intention to adopt high speed Internet, as did Brown and Venkatesh (2005) for the PC, then we used the dependent variable user satisfaction instead of behavioral intention. And the model explained 49.2 percent of the variance in satisfaction of using high speed Internet by people in household (see Table 7 and Figure 2). Thus, in this study, using a different dependent variable than did Brown and Venkatesh (2005), that is user satisfaction instead of behavioral intention, our research model explained the same percentage of variance than those explained by MATH alone (e.g., without the household life cycle characteristics and using behavioral intention as dependent variable).

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 independent variable mobility than we included in the present study in which we investigated satisfaction of using high speed Internet at home. And our model explained the same percentage of variance in intention to buy a mobile phone than in the present study in satisfaction of using high speed Internet, that is, 50 percent. According to this finding, we can then see that the variable user satisfaction is as much appropriate as dependent variable in the research model proposed by Brown and Venkatesh (2005) than is behavioral intention. And this finding is also consistent with what is argued by Brown et al. (2006), that is, the model is expected to generalize to other IT products and systems in the household context. However, when the dependent variable of the model is interchanged (e.g., user satisfaction instead of behavioral intention) as did Fillion and Le Dinh (2008) and Fillion and Booto Ekionea (2010b) in studies examining the determining factors in the use of mobile phone, it seems that high speed Internet (the technology involved in the present study) is a more appropriate technology to examine than is mobile phone, since the amount of variance explained by the model in the present study is largely superior, that is, 50 percent comparatively to 32 percent and 35 percent respectively for the two studies on the mobile phone quoted above. Besides, it is to be noted that, in the model we used in this study, less independent variables showed to be good predictors in satisfaction of using high speed Internet by people in household than in the two studies quoted above examining the predictors in satisfaction of using mobile phone by people in household. So, this study brings several interesting findings which contribute to the technology adoption and use literature by offering key insights regarding the differences between adoption, use, and satisfaction of using technology at home.

First, our main findings regarding user satisfaction of a certain technology are consistent with those got in Tao et al.'s (2009) study in the sense that several variables have a significant effect on user satisfaction, but other variables need an improvement on some elements, for example, consumer service, transmission line and connection stability need to be improved in Tao et al.'s (2009) study, while other's usage influences, utility for work-related use as well as applications for personal use need to be improved in our study. Second, we found seven very important variables that seem to be good predictors in satisfaction of using high speed Internet at home, and more particularly perceived ease of use, cost, applications for fun, age, and the new variable that we added to the Brown and Venkatesh's (2005) model, mobility (see Table 7). And the fact that the moderator variable age has been found a very significant predictor (taken as independent variable) in satisfaction of using high speed Internet and a very significant influencing factor (taken as moderator variable) in all hypotheses supported in the study provides additional evidence concerning the importance of integrating household life cycle stage in research examining household technology adoption and use. These seven variables are also important to take into account by high speed Internet providers in order to improve actual services, to offer new services still better adapted to people's needs, as well as to perform their sales marketing. Third, we found that people are, to some extent, using high speed Internet for a matter of mobility given our new variable mobility showed to be the more significant in the study (see Table 7). Fourth, we found that, depending on the technology studied, the dependent variables behavioral intention and user satisfaction might be interchanged in the model proposed by Brown and Venkatesh (2005) given the amount of variance explained by the models are quite varying across technologies and dependent variables observed. The dependent variable *use behavior* proposed by Thompson et al. (1991) and the dependent variable *user satisfaction* (examined in the present study) conceptualized in the work of Cyert and March (1963), and initially developed by Ives et al. (1983), may also be further tested in future studies. And, finally, we suggest the test of new independent variables which may explain a greater amount of variance in satisfaction of using high speed Internet by people in household in future studies. To that end, we recommend three new independent variables in the next paragraph.

Indeed, depending on the technology examined, it would be interesting in future studies to add a variable such as *utility for security* (in utilitarian outcomes) to the theoretical research model suggested by Brown and Venkatesh (2005) augmented with the new variable mobility that we tested in this study. This variable has been found very significant in the case of mobile phone technology in the studies conducted by Fillion and Berthelot (2007), Fillion and Le Dinh (2008), as well as Fillion and Booto Ekionea (2010b). Who knows, people might be also using high speed Internet for a matter of their own security and those of their family given this technology allows to rapidly communicate with helping people or organisms everywhere in the world. The variable *social norm* might be also added in social outcomes. Who knows, people might be using high speed Internet just to do as everybody. And the variable *provider support* might be added in external control beliefs. People might be according a great importance to the quality of support offered by the high speed Internet provider. It would be also interesting to test the actual model in other situations and with other populations. For example, with colleagues from Brasil (University of Lavras) and Cameroon (University of Yaounde I), we are now testing the actual model with people who are using a mobile phone at home. As in this study, we used the dependent variable user satisfaction since the respondents are already using a mobile phone. The results of these studies will follow in subsequent papers. It will be interesting to see whether the results remain the same as those got from people who are using high speed Internet in household.

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 of using high speed Internet 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. So, rest assured that we will continue to inquire into this new and exciting field.

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REFERENCES

Al-Omoush, K.S. & A.A. Shaqrah (2010). An empirical study of household Internet continuance adoption among Jordanian users. *International Journal of Computer Science and Network Security*, *10*(1), 32-44.

Anderson, B. (2008). The social impact of broadband household Internet access. *Information, Communication, & Society*, *11*(1), 5-24.

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

Brown, S.A., V. Venkatesh & H. Bala (2006). Household technology use: Integrating household life cycle and the model of adoption of technology in households. *The Information Society*, *22*, 205-218.

Brown, S.A. & V. Venkatesh (2005). Model of adoption of technology in households: A baseline model test and extension incorporating household life cycle. *MIS Quarterly*, *29*(3), 399-426.

Cambini, C. & Y. Jiang (2009). Broadband investment and regulation: A literature review. *Telecommunications Policy*, *33*, 559-574.

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

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

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

Compeau, D.R. & C.A. Higgins (1995a). Application of social cognitive theory to training for computer skills. *Information Systems Research*, *6*(2), 118-143.

Compeau, D.R. & C.A. Higgins (1995b). Computer self-efficacy: Development of a measure and initial test. *MIS Quarterly*, *19*(2), 189-211.

CRACIN (2005). *Written Submission to Telecommunications Policy Review Panel*. Toronto: Canadian Research Alliance for Community Innovation & Networking.

Cyert, R.M. & J.G. March (1963). *A Behavioral Theory of the Firm*. Englewood Cliffs, NJ: Prentice-Hall.

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

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

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

Digital Home (2009). Canada ranked fifth in broadband penetration. Retrieved August 6, 2010, from http://www.digitalhome.ca/ 2009/09/canada-ranked-fifth-in-broadband-penetration/.

Dumitru, R.C., T. Bürkle, S. Potapov, B. Lausen, B. Wiese & H.-U. Prokosch (2007). Use and perception of Internet for health related purposes in Germany: Results of a national survey. *International Journal of Public Health*, *52*, 275-285.

Dunn, J. (2010). Digital home thoughts: High-speed Internet access in Canada: It's expensive and slow. Digital Home Thoughts, http://www.digitalhomethoughts.com/news/show/97187/high-speed-internet-access-in-canada. Retrieved August 9, 2010.

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

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

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

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

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

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

Fillion, G. & S. Berthelot (2007). An extended model of adoption of technology in households: A model test on people's intention to adopt a mobile phone. *Management Review: An International Journal*, *2*(2), 4-36.

Fuhr, J.P. & S.B. Pociask (2007). Broadband services: Economic and environmental benefits. Retrieved August 9, 2010, from, http://www.theamericanconsumer.org/2007/10/31/broadband-services-economic-and-environmental-benefits/.

Gill, K.E. (2010). What does 'high speed Internet' mean exactly?. Retrieved August 6, 2010, from http://wiredpen.com/2010/ 03/26/what-does-high-speed-internet-mean-exactly/.

Government of Canada (1999). Speech from the throne to open the second session of the 36th parliament of Canada. http://www.pco-bcp.gc.ca/default.asp?Language=E&Page=InformationResources&sub=sftddt&doc= sftddt1999_e.htm. Retrieved August 6, 2010, from

Government On-Line Advisory Panel (2003). *Connecting with Canadians: Pursuing Service Transformation*. Ottawa: Treasury Board of Canada.

Helsper, E.(2010). Gendered Internet use across generations and life stages. *Communication Research*, *37*(3), 352-374.

Hobbs, V.M. & D.D. Osburn (1989). *Distance Learning Evaluation Study Report II: A Study of North Dakota and Missouri Schools Implementing German I by Satellite*. ERIC ED 317 195.

Horrigan, J. (2009). *Home Broadband Adoption 2009*. Report for the Pew Internet & American Life Project, Retrieved August 6, 2010, from http://pewinternet.org/Reports/2009/10-Home-Broadband-Adoption-2009.aspx. [Accessed 6 August 2010]

Howard, P.N. & N. Mahazeri (2009). Telecommunications reform, Internet use and mobile phone adoption in the developing world. *World Development*, *37*(7), 1159-1169.

Ida, T. & K. Sakahira (2008). Broadband migration and lock-in effects: Mixed logit model analysis of Japan's high speed Internet access services. *Telecommunications Policy*, *32*, 615-625.

Ives, B., M.H. Olson & J.J. Baroudi (1983). The measurement of user information satisfaction. *Communications of the ACM*, *26*(10), 785-793.

Jones, S. & S. Fox (2009). *Generations Online in 2009*. Report for the Pew Internet & American Life Project, January 28, 2009.

Kwon, H.S. & L. Chidambaram (2000). A test of the technology acceptance model: The case of cellular telephone adoption. *Proceedings of HICSS-34*, Hawaii, January 3-6.

Labriet-Gross, H. (2007). High speed Internet: Can broadband save the planet?. L'Atelier North America, Retrieved August 9, 2010, from http://www.atelier-us.com/internet-usage/article/high-speed-internet-can-broadband-save-the-planet.

Majumdar, S.K. (2008). Broadband adoption, jobs and wages in the US telecommunications industry. *Telecommunications Policy*, *32*, 587-599.

Matthews, D. & L. Schrum (2003). High-speed Internet use and academic gratifications in the college residence. *The Internet and Higher Education*, *6*(2), 125-144.

Middleton, C.A. & J. Ellison (2006). *All Broadband Households Are Not the Same: Why Scope and Intensity of Use Matter*. Report for Ryerson University, Toronto.

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

National Broadband Task Force (2001). *The New National Dream: Networking the Nation for Broadband Access*. Ottawa: Industry Canada.

Orazem, P.F. (2005). *The Impact of High-Speed Internet Access on Local Economic Growth*. Research Report Prepared for University of Kansas School of Business, Topeka, Kansas.

Perry, T.T., L.A. Perry & K. Hosack-Curlin (1998). Internet use by university students: An interdisciplinary study on three campuses. *Internet Research*, *8*(2), 136-141.

Platt, R.G., W.B. Carper & M. McCool (2010). Outsourcing a high speed Internet access project: An information technology class case study in three parts. *Journal of Information Systems Education*, *21*(1), 15-25.

Rains, S.A. (2008). Health at high speed: Broadband Internet access, health communication, and the digital divide. *Communication Research*, *35*(3), 283-297.

Rosston, G., S.J. Savage & D.M. Waldman (2010). *Household Demand for Broadband Internet Service*. Final Report for the Broadband.gov Task Force, Federal Communications Commission (FCC).

Selouani, S.. & H. Hamam (2007). Social impact of broadband Internet: A case study in the Shippagan area, a rural zone in Atlantic Canada. *Journal of Information, Information Technology, and Organizations*, *2*, 79-94.

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

Tao, C.J., S.C. Chen & L. Chang (2009). Apply 6-Sigma methodology in measuring the competition quality of satisfaction performance -- An example of ISP industry. *Quality & Quantity*, *43*, 677-694.

Taylor, S. & P.A. Todd (1995). Understanding information technology usage: A test of competing models. *Information Systems Research*, *6*(2), 144-176.

Telecommunications Policy Review Panel (2006). *Telecommunications Policy Review Panel -- Final Report 2006*. Ottawa: Industry Canada.

Thompson, R.L., C.A. Higgins & J.M. Howell (1991). Personal computing: Toward a conceptual model of utilization. *MIS Quarterly*, *15*(1), 124-143.

Varon, E. (2010). Testing the benefits of high-speed Internet access. Appeared on NetworkWorld, Retrieved August 9, 2010, from http://www.netorkworld.com/news/2010/051710-testing-the-benefits-of-high-speed.html.

Venkatesh, V. & S.A. Brown (2001). A longitudinal investigation of personal computers in homes: Adoption determinants and emerging challenges. *MIS Quarterly*, *25*(1), 71-102.

Wagner, J. & S. Hanna (1983). The effectiveness of family life cycle variables in consumer expenditure research. *Journal of Consumer Research*, *10*, 281-291.

Webster, J. & J.J. Martocchio (1993). Turning work into play: Implications for microcomputer software training. *Journal of Management*, *19*(1), 127-146.

Webster, J. & J.J. Martocchio (1992). Microcomputer playfulness: Development of a measure with work place implications. *MIS Quarterly*, *16*(2), 201-226.

Windhausen Jr., J. (2008). *A Blueprint for Big Broadband*. Report for EDUCAUSE, Washington D.C., Retrieved August 9, 2010, from http://www.educause.edu.

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

MULTI-FACTOR USER INTERFACE COMPONENTS LAYOUT PROBLEM WITH GENETIC ALGORITHM

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ABSTRACT

Multi-factor user interface components layout problem involves a number of qualitative and quantitative factors in the objective function. There is much literature reporting the use of facilities layout models for the user interface components layout problem. The solutions obtained using the traditional layout procedures, namely construction and improvement procedures, are expected to be sub-optimal. Hence, search techniques are used to evaluate the near optimal solution from the population of initial solutions. This paper presents a genetic algorithm approach to obtain the near optimal layout, from the population of initial layouts of the multi-factor user interface components layout problem for the example task under consideration. The resulting layouts are compared with that of the improvement procedure for the reported case under consideration.

INTRODUCTION

The well-designed user interface makes an interactive system effective enabling user to concentrate on their work, exploration, or pleasure. The ability to perform routine activities quickly, effortlessly, and without conscious awareness is called automaticity (Logan, 1988). Automaticity is relevant and important construct for the study of human-computer interaction in general and for the study of direct manipulation of interfaces in particular. Some studies show that the total time required to complete the task is a direct manipulation interface will be less than in a menu based interface (Lim et al., 1996).

Within the computer science, there is a growing awareness of the need for great attention to human factors issues. The business cases for human factors in computer and information systems are strong as demonstrated by many successful products whose advantage lay in their superior user interface. There is a one-to-one relationship between the facilities layout problem in a manufacturing plant and the user interface components layout problem in human-computer interface design (Peer et al., 2004). The quadratic assignment problem (QAP) formulation for assigning 'n' facilities to 'n' mutually exclusive locations is the most typical model used in manufacturing or interactive service systems.

A classical QAP is formulated handling qualitative (subjective) factor(s) and quantitative (objective) factor(s) to obtain the layouts, using construction procedure or improvement procedure. The multi–criteria facilities layout model handles a number of criteria values associated in the multiple qualitative and quantitative factors with the objective function of the quadratic assignment problem (QAP). Harmonosky and Tothero (1992) presented a quadratic assignment model to handle the multiple qualitative and quantitative factors in the same manner when applying them into the objective function. Then, a construction procedure was proposed, in which the pair of facilities with least composite criterion value is selected to place far apart in the layout to obtain the initial layouts. The resulting initial layouts may be improved further by using the improvement procedures. Peer et al. (2003) used the multi-factor facilities layout model of Sharma and Peer (2005) in which multiple qualitative and quantitative factors were handled in different manner separately to obtain the alternate layouts of the user interface components of the example task under consideration. Then, the search techniques such as simulated annealing (Suresh and Sahu, 1993), ant colony optimization technique (Baykasoglu, 2006), genetic algorithm, etc. are used to obtain the best layouts.

Good heuristic techniques are necessary to obtain the best layouts due to its high computational complexity. Modern heuristic techniques, namely genetic algorithms (Goldberg, 1989; Michalewicz, 1996), taboo search (Kaku and Mazzola, 1997), simulated annealing (Baykasoglu and Gindy, 2001) and ant colony optimization (Baykasoglu et al., 2006), can be good candidates for this problem. Genetic algorithms (GAs) have been applied extensively to solve many real-world problems. Conway and Venkataramanan (1994) examined the suitability of genetic algorithm for the dynamic layout problem (DLP). Tate and Smith (1995) used a GA to solve QAP. Suresh et al. (1995) also proposed a GA for obtaining efficient layouts. Balakrishnan and Cheng (2000) presented a GA for DLP. Deb et al. (2001) and Deb and Bhattacharyya (2003, 2005) applied GA and simulated annealing for a facility layout problem (FLP).

In this paper, we present a genetic algorithm approach to obtain the best layout from the population of the initial layouts of the multi-factor user interface components layout problem for the example task under consideration as given in Peer et al. (2003). Then, the final layouts are compared with that of the improvement procedure for the reported case under consideration.

The paper is organized into 5 sections. Section 2 presents the solution procedure of genetic algorithm. The resulting layouts obtained from the population of initial layouts of the user interface components layout problem for the example task are presented in section 3. Section 4 reports the computational results and the paper ends with conclusions in section 5.

SOLUTION PROCEDURE OF GENETIC ALGORITHM

Genetic search technique works with coding variables, since the coding of variable space discretizes the continuous search space (Rajasekharan and Pai, 2005). It uses population of points at one time, which means that it processes number of designs at the same time. It consists of randomized operators, rather deterministic transition rules used in traditional optimization methods.

Genetic search technique starts with a set of solutions called population. The solutions of this population are used to form a new population with better solution based on their fitness. This procedure is repeated until the conditions for improvement of best solution are satisfied. The members in population may be represented by string bits, arrays, trees, lists or any other valid data structure form. In order to make use of the fundamental theorem of genetic algorithms, the data structure of string bits representing the member of population is used (Conway and Venkataramanan, 1994).

Reproduction operator is used to select chromosomes or parent from population. The various methods are used to select parent chromosomes, such as roulette wheel selection, Boltzmann selection, Tournament selection, Rank selection, and steady-state selection. Reproduction makes clones of good strings, but does not create new ones.

Then, crossover operator is applied to the mating pool to create better string by preserving the information of parent strings. Crossover proceeds in three steps. First, the reproduction operator selects a random pair of two individual strings for mating, then a cross-site is selected at random along the string length and the position values are swapped between two strings. The crossover rate is the probability of cross over (p_c), which varies from 0 to 1. It is the ratio of the number of pairs to be crossed to some fixed population. If good strings are not created by crossover, they will not survive too long, because reproduction will select against those strings in subsequence generations. That is, the effect of crossover may either be detrimental or beneficial all the strings in mating pool are not used in crossover, in order to preserve some of good strings. When the crossover probability is p_c, their 100 p_c percent strings in the population are used in the crossover operation.

Finally, mutation is used to modify errors in strings caused in the previous operations. The mutation operator introduces new genetic structure in the population randomly modifying some of its building blocks. The bit-wise mutation is performed bit-by-bit by flipping a coin with a probability of p_m. A number between 0 and 1 is chosen at random. If the random number is smaller than pm, then the outcome of coin slipping is true, otherwise the outcome is false. If at any bit, the outcome in true then the bit is altered, otherwise the bit is kept unchanged. The bits of the strings are independently muted. That is, the mutation of bit does not affect the probability of mutation of other bits. Mutation rate is the probability of mutation (p_m), which is used to calculate number of bits to be muted.

The next section of the paper presents the example task under consideration for the user interface components layout problem and its resulting layouts.

LAYOUTS OF USER INTERFACE COMPONENTS

There is much literature available, using the facilities layouts models for the user interface components layout problem (Peer and Sharma, 2004; Sharma, Peer and Alade, 2005; Peer et al., 2004). It is involved with the application of construction/improvement procedures to obtain the layouts of user interface components for the example task under consideration. In order to obtain the best layout, it is required to use the search techniques. In this section, genetic search technique is used to improve the solution of layouts obtained with the construction procedure for the multi-factor user interface components layout problem using the Peer and Sharma (2005) model as given in equations (1) through (4).

Minimize $$Z=\sum_{i=1}^{n}\sum_{j=1}^{n}\sum_{k=1}^{n}\sum_{l=1}^{n}(W_1R_{ik}+W_2F_{ik})\ d_{jl}X_{ij}X_{kl} \quad (1)$$

Subject to: $$\sum_{i=1}^{n}X_{ij}=1, \quad j=1,2,\ldots,n \quad (2)$$

$$\sum_{j=1}^{n}X_{ij}=1, \quad i=1,2,\ldots,n \quad (3)$$

$$X_{ij}=0 \text{ or } 1, \forall\ i,j \quad (4)$$

Where $$R_{ik}=\sum_{p=1}^{u}\beta_p R_{ikp}, \ \forall\ i,k$$

$$F_{ik}=\sum_{q=1}^{w}\gamma_q F_{ikq}, \ \forall\ i,k$$

β_p = Weight assigned to qualitative factor *p*

γ_q = Weight assigned to quantitative factor *q*

R_{ikp} = Normalized relationship value between components *i* and *k* for factor *p*

F_{ikq} = Normalized relationship value between components *i* and *k* for factor *q*

R_{ik} = Combined qualitative factor

F_{ik} = Combined quantitative factor

u = number of qualitative factors

w = number of quantitative factors

n = number of components

i and *k* indices for components numbers, and *j* and *l* are indices for location numbers.

The combined qualitative factor (R_{ik}), combined quantitative factor (F_{ik}), composite factor ($A_{ik}=W_1 R_{ik}+W_2 F_{ik}$) obtained for W_1 = 0.2 and W_2=0.8 and the distances (d_{jl}) between locating j and l are given as shown in the Figure1, for the example task presented in Sharma, Peer and Alade (2003).

Figure 1: Combined qualitative factor (R_{ik}), combined quantitative factor (F_{ik}), composite factor (A_{ik}) for W_1 = 0.2 and W_2 =0.8 and distances(d_{jk})

R_{ik}=

	1	2	3	4	5	6
1	-	0.033	0.024	0.035	0.028	0.038
2	0.033	-	0.038	0.025	0.019	0.045
3	0.024	0.038	-	0.035	0.019	0.046
4	0.035	0.025	0.035	-	0.042	0.046
5	0.028	0.019	0.019	0.042	-	0.035
6	0.038	0.045	0.041	0.046	0.035	-

F_{ik}=

	1	2	3	4	5	6
1	-	0.038	0.016	0.037	0.033	0.035
2	0.038	-	0.029	0.027	0.048	0.032
3	0.016	0.029	-	0.031	0.033	0.028
4	0.037	0.027	0.031	-	0.029	0.40
5	0.033	0.048	0.33	0.029	-	0.38
6	0.035	0.032	0.028	0.040	0.38	-

A_{ik}=

	1	2	3	4	5	6
1	-	0.037	0.018	0.037	0.032	0.036
2	0.037	-	0.031	0.027	0.042	0.035
3	0.018	0.031	-	0.032	0.030	0.032
4	0.037	0.027	0.032	-	0.032	0.041
5	0.032	0.042	0.030	0.032	-	0.037
6	0.036	0.035	0.032	0.041	0.037	-

d_{jl}=

	1	2	3	4	5	6
1	-	3	6	3	5	7
2	3	-	3	5	3	5
3	6	3	-	8	6	3
4	3	5	8	-	3	6
5	5	3	6	3	-	3
6	7	5	3	6	3	-

A sample of 10 layouts and their scores obtained using construction procedure are given as shown in Figure 2.

Figure 2: Layouts and Scores obtained with construction procedure for the user interface components layout problem.

Layouts			Scores
2	3	6	2.319
1	4	5	
5	3	2	2.326
4	1	6	
5	6	4	2.342
1	3	2	
6	1	5	2.365
2	3	4	
6	3	2	2.441
5	1	4	

Layouts			Scores
4	3	5	2.353
2	6	1	
1	3	2	2.352
5	4	6	
2	4	1	2.329
6	3	5	
5	4	3	2.354
1	6	2	
2	6	5	2.321
4	3	1	

In order to apply the fundamental theorem of genetic algorithm, the data structure (string) representing the member of the population is defined because of the following reasons (Conway and Venkataramanan, 1994). (1) The objective value of the feasible objective function can easily be calculated for the string chosen to crossbreed. (2) The first period layout is related to the second period layout by way of changeover cost and within by layout quality. That is, any element of the string is related only to its immediate layout and the two surrounding layouts. (3) Schema, or sub-strings, which are short, low order, and have an average fitness will be expected to survive.

Let the string representing the member of the population P is m, n is the number of components. Then $P = a_{11}\ a_{21}\ a_{31} \ldots a_{n1.}\ b_{12}\ b_{22} \ldots b_{n2} \ldots P_{1n.}\ P_{2n} \ldots P_{nn}$ where a_{j1} is the component number in the location j of population number 1, b_{j2} is the component number in location j of population number 2 and P_{jm} is the component number in location j of population number m. The strings are separated by one place leaving the schema (sub-string) together. For n=4, m=3, P=2413 4132 3214 is interpreted as component 2 is in location 1 in the population number 1 and so on.

The population size of 10 layouts of user interface components layouts with 6 components as shown in Figure 2 is considered for the application of GA search technique to obtain the final layout. Each layout of 6 components is represented as a string of 6 decimal digits as follows.

236145	532416	432516	346125	156324
526134	256143	641235	132645	351462

Reproduction operator is used on population to select the chromosomes for parents to crossover. It is performed with Roulette wheel selection method (Rajasekaran and Pai, 2005) to choose the strings of feasible solution as chromosomes. Thus, the pair of strings is selected from the population according to the distribution of the relative strength of the strings to the entire strength of the population.

Then, a cross-site is selected at random along string length and the strings are split as follows.

236145	532416	|	432 516	346125	156324
526134	256143	|	641 235	132645	351462

Next, the sub-strings to the visit of cross-site are swapped as follows.

236145	532416	432 ab5	132645	351462
526134	256143	c4d 516	346125	156324

Since the cross-site selected for split of the string is the middle of a single period layout, the stronger of the two strings regains the partial layout and the weaker fills in the unassigned component positions, which correspond and are feasible (Conway and Venkataramanan, 1994). Remaining positions are filled by unassigned components which correspond to their neighboring feasible layouts and then by randomly. Hence, the 'a' becomes a 6 because the period has a 6 in the fourth position, which forces the 'b' to become a 1. The 4 is carried from weaker string to get feasible solution. Similarly, the 'c' becomes 3 because the period has a 3 in the first position, which forces the 'd' to become 2 and resulting strings of the population are obtained as follows.

236145	532416	432615	132645	351462
526134	256143	342516	346125	156324

Decimal digits are used to represent the strings in population and hence, the use of mutation operation does not guarantee the feasible solution.

Finally, the scores of the layouts in the population are computed and compared with the least initial score of the layout, in order to determine the improved layout after the first generation. The basic steps involved in genetic search technique for the multi-factor user interface components layout problem are given in Figure 3. The genetic search technique is repeated for 50 generations and the score of the final layout is obtained as follows.

6	4	3
1	5	2

=2.252

The percentage of improvement over the least initial layout score of construction procedure is computed as shown in Figure 4.

Figure 3: Flow Chart of Genetic Search Technique for the Problem

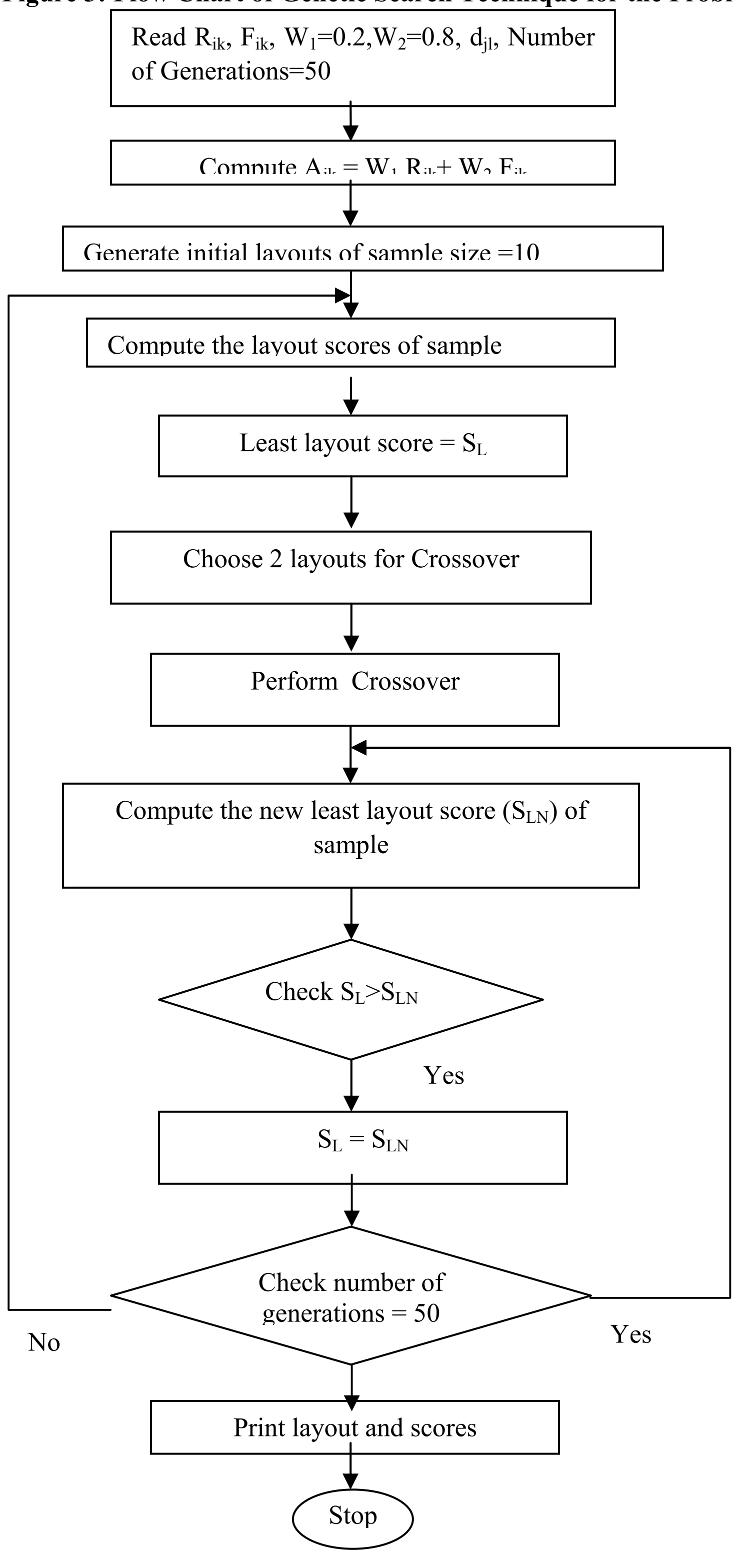

Figure 4: Percentage of improvement with genetic search technique over construction procedure for $W_1 = 0.2$ and $W_2 = 0.8$

Construct procedure Layout			Score	Genetic Search technique Layout			Score	Improvement (%)
5	3	2	2.316	6	4	3	2.252	2.8
4	1	6		1	5	2		

The genetic search technique is used to obtain the best layout for the populations of construction procedure for different combinations of weights and compared as given in Table 1. From the results, it is observed that the solution obtained with genetic search technique is improved by an average 3.92 percent whereas the same is improved by an average 2.30 percent with improvement procedure.

COMPUTATIONAL RESULTS

Genetic algorithm is used to evolve the population of initial solution into optimal solution. In this paper, genetic search technique is used to obtain the best final layouts from the initial population of construction procedure for the user interface components layout problem of 2 by 3 as given in Sharma, Peer and Alade (2003). For each combination of weights W_1 and W_2, the population size of 10 layouts is obtained with construction procedure. The generic search technique is used for 50 generations to obtain the best layout. The layout obtained with each generation is compared with that of the least score layout obtained with the construction procedure. The score of the final layout obtained with genetic search technique is compared with the least score layout of construct procedure for all the combinations of weights W_1 and W_2 assigned to combined qualitative factor and combined quantitative factor. It is observed form the results that the solution obtained with genetic search technique is improved by an average 3.92 percent, whereas the same is improved by an average 2.30 percent with improvement procedure. The ‘C’ program of genetic search technique for this problem is run on the P-IV system.

Table 1: Comparison of Results of Genetic Search Technique with Construction Procedure: Area limited to 2 rows and 3 columns

Weight		Construction procedure		Improvement procedure			Genetic search technique		
W_1	W_2	Layout	Score	Layout	Score	Improvement over construction procedure (%)	Layout	Score	Improvement over construction procedure (%)
0.0	1.0	5 4 3 1 6 2	2.255	4 1 2 6 5 3	2.241	0.62	1 2 5 4 6 3	2.213	2.52
0.2	0.8	2 3 6 1 4 5	2.319	3 6 5 2 4 1	2.282	1.60	6 4 3 1 5 2	2.252	2.80
0.4	0.6	3 1 4 5 2 6	2.241	5 4 1 3 6 2	2.225	0.71	5 2 3 1 6 4	2.217	1.10
0.5	0.5	4 6 5 1 2 3	2.293	2 6 1 3 5 4	2.259	1.48	2 6 1 3 4 5	2.233	2.62
0.6	0.4	2 5 4 3 1 6	2.317	5 4 1 3 6 2	2.234	3.58	5 4 3 1 6 2	2.219	4.23
0.8	0.2	2 3 4 6 1 5	2.318	2 6 1 3 5 4	2.234	3.62	4 5 1 3 6 2	2.227	3.93
1.0	0.0	3 2 1 6 5 4	2.326	4 1 2 5 6 3	2.222	4.47	1 6 2 5 4 3	2.088	10.23
				Avg. improved (%)		2.30	Avg. improved (%)		3.92

CONCLUSIONS

Genetic algorithm is used efficiently to evolve the population of initial solutions into near optimal solution, once the data structure of solution is chosen so that the fundamental theorem of genetic algorithm can be applied. The structure of genetic algorithm is exploited to use it in parallel processing. This technique is found to be best suited to evaluate the obtained solution from the initial population of solutions, and hence the best solution is guaranteed compared to the heuristic procedure such as improvement procedure of the layout problems that uses one solution to improve it further. Since, large number of solutions may be obtained for the different combination of weights W_1 and W_2 with genetic search technique; this problem could easily be extended to interface with a decision support system.

REFERENCES

Balakrishnan, J. & C.H. Cheng (2000). Genetic search and the dynamic layout problem. *Computers & Operations, Research*, 27(6), 587-593

Baykasoglu, A. & N.N.Z. Gindy (2001). A simulated annealing algorithm for dynamic layout problem. *Computers & Operations Research*, 28,1403–1426.

Baykasoglu, A., T. Dereli & I. Sabuncu (2006). An ant colony algorithm for solving budget constrained and unconstrained dynamic facility layout problems. *Omega*, 34, 385–396

Conway, D.G. & M.A. Venkataramanan (1994). Genetic search and the Dynamic facility layout problem. *Computers & Operations Research*, 21(8), 955-960.

Deb, S.K., B. Bhattacharyya & S.K. Sorkhel (2001). Hybrid genetic algorithm for facility layout design under manufacturing environment. *Proceedings of the International Conference on Operational Research*, Kolkata, India, 56–68.

Deb, S.K. & B. Bhattacharyya (2003). Manufacturing facility layout design based on simulated annealing. *Proceedings of the National Conference on Advances in Manufacturing Systems*, Kolkata, India, 117–122.

Deb, S.K. & B. Bhattacharyya (2005). Solution of facility layout problems with pickup/drop-off locations using random search techniques. *International Journal of Production Research*, 43(22), 4787–4812.

Goldberg, D.E. (1989). *Algorithms and search optimization and machine learning* (Reading MA: Addison-Wesley).

Harmonosky, C.M. & G.K. Tothero (1992). A multi-factor plant layout methodology. *International Journal of Production Research* 30(8), 1773-1789.

Kaku, B.K. & J.B. Mazzola (1997). A tabu search heuristic for the dynamic plant layout problem. *INFORMS: Journal on Computing*, 9, 374–84.

Lim, K.H., I. Benbasat & P.A. Todd (1996). An experimental investigation of the interactive effects of interface style, instructions, and task familiarity on user performance. *ACM Transactions on Computer-Human Interaction*. 3(1), 1-37.

Logan, G. D. (1988). Automaticity, resources and memory: theoretical controversies and practical implications. *Human Factors*, 30(5), 583-598.

Michalewicz, Z. (1996). *Genetic algorithms + data structures = evolution programs (Third Edition)*, Springer-Verlag.

Peer, S.K. & Dinesh K. Sharma (2004). Single objective layout design of user interface components with multiple qualitative factors. *International Journal of Applied Mathematics and Computing,* 14(1-2), 353-363.

Peer, S.K., D.K. Sharma, K. Ravindranath & M. M. Naidu (2004). Layout design of user interface components with multiple objectives. *Yugoslav Journal of Operations Research,* 14 (2), 171-192.

Rajasekaran, S. & G.A.V. Pai (2005). *Neural works, fuzzy logic and genetic algorithms: synthesis and applications*. Prentice Hall India Ltd., Publisher.

Sharma, Dinesh K., S.K. Peer & Hari P. Sharma (2005). Quadratic assignment formulation for the multi-factor facilities layout problem. *International Journal of Modelling and Simulation*. 25(1), 57-66.

Sharma, Dinesh K., S.K. Peer & Julius A. Alade (2003). A multi factor user interface components layout problem. *Journal of Business and Economics Research*, 1(10), 81-92.

Suresh, G. & S. Sahu (1993). Multi objective facility layout using simulated annealing. *International Journal of Production Economics*, 32, 239–254.

Suresh, G., V.V. Vinod & S. Sahu (1995). A genetic algorithm for facility layout. *International Journal of Production Research*, 33, 3411–3423.

Tate, D.M. & A.E. Smith (1995). A genetic approach to the quadratic assignment problem. *Computers & Operations Research,* 22,73–83.

SOCIAL CAPITAL AND IS LEADERSHIP: A CONCEPTUAL FRAMEWORK

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ABSTRACT

The value of information technology and how it is effectively managed is an important area of research. Social capital, as a relatively new concept, has yet to be applied to the specific issues affecting IS management. The main purpose of this paper is to propose a model for the impact on social capital development of the "system of knowing" of the IS leader and specific characteristics of the IS leader. We synthesize the social capital literature and propose a framework for IS leadership social capital development. The main theoretical contribution is to provide a framework for understanding the social capital implications on IS leadership success based on Seiber, Kraimer and Liden's model for career success. To that end, a number of propositions are presented to guide future research. We further suggest managerial and theoretical implications.

INTRODUCTION

The 2007 economic downturn initiated multiple waves of change for IT management with cost cutting and IT investment scrutiny pushing companies into the mode of doing more with less. Additional challenges are seen in 2009 with "mindsets … shifting away from how to cut IT costs to how to help the business grow" (Bednarz, 2010, p. 14). With the decrease in IT investments coupled with higher strategic advantage expectations for the IT investments being made, it becomes increasingly critical to be able to explain why and how certain information technology (IT) investments are competitively successful and others are not. One explanation is linked to the use of superior IT managerial skills (Bharadwaj, 2000; Mata, Fuerst & Barney, 1995). These skills comprise one form of human capital, i.e. the category of capital that deals with the skills and capabilities of individuals in an organization that are used to enable individuals to act in new ways (Coleman, 1988). Even though IT managerial skills have been identified as important assets for firms in their pursuit of successful competition, those skills may not translate into successful action for the organization without the appropriate communication network. Burt (1997) pointed out "while human capital is surely necessary to success, it is useless without the social capital of opportunities in which to apply it" (p.339).

Although social capital has always been a part of the fabric of organizational life, until recently the term "social capital" has been associated with and used to explore individuals and social groups such as communities and nations. Cohen and Prusak (2001) attributed this focus to the mechanistic nature of organizations which hid the social aspects. Social capital research has grown since its introduction, encompassing such dependent variables as career success (Seibert, Kraimer & Liden, 2001), employment practices, creation of human capital (Coleman, 1988) and occupational status (Flap & DeGraaf, 1989). While its application in the information systems (IS) research area has touched on portions of the social capital concept such as (social) networking and power (Applegate & Elam, 1992) and partnering relationships between IT and business unit relationships (Ross, Beath & Goodhue, 1996), it has not been studied as the comprehensive, specific conceptualization envisaged by contemporary social science researchers, such as Cohen and Prusak (2001), Coleman (1988), and Lin (2001).

An obvious question is, if social capital has always been a part of organizations, why is it important to pay explicit attention to it now? "What in the past could be taken for granted and sometimes even minimized can no longer be ignored or left to chance. This is true in part because organizations in a changing highly competitive global economy need to make the most of their assets, of which social capital is key" (Cohen & Prusak, 2001, p.16). This imperative leads to the proposal that utilizing the concept of social capital to analyze the impact of IS leaders on their organizations would lend valuable insight into how IT is effectively managed in organizations.

Researchers and practitioners continue to debate the value of IT in today's organization (e.g. Carr, 2003), trying to find antecedents for successful IT investments. One of those antecedents might be the social capital the IS leader creates which could enable the IS human capital to be more effective and productive.

THERETICAL BACKGROUND: SOCIAL CAPITAL

Basic Concept

There are many definitions of social capital and an equally diverse group of benefits (see Table 1). While they all have their foundation in social relations, different views develop from the different perspectives and levels of analysis followed. It is proposed that there is no one right approach when analyzing social capital relative to IT investment success. Thus, an overview of the concept including the main approaches is appropriate.

Social capital can be defined as that part of social structure that adds value and facilitates the actions of the individuals within that structure (Coleman, 1988). This concept parallels the concepts of physical capital facilitating production and human capital facilitating an individual's effectiveness through changes to their individual skills and capabilities (Coleman, 1988) Cohen and Prusak (2001) looked to an organizational setting context, particularly to explore investments in and returns from social capital:

Social capital consists of the stock of active connections among people: the trust, mutual understanding, and shared values and behaviors that bind the members of human networks and communities and make cooperative action possible. (p.4)

Table 1: Definitions and Benefits of Social Capital

Origin	Definition	Key Benefits	Focus
Coleman (1988)	"Social capital is defined by its function. It is not a single entity, but a variety of different entities having two characteristics in common: They all consist of some aspect of social structure, and they facilitate certain actions of individuals who are within the structure"" (p.302).	Enhanced information acquisition Transfer of authority or rights of control	Internal
Bourdieu (1985)	"the aggregate of the actual or potential resources which are linked to possessions of a durable network of more or less institutionalized relationships of mutual acquaintance or recognition" (p.248).	Access to resources	External
Burt (1997)	"A function of brokerage opportunities in a network" (p.339)	Access to information Timing of information acquisition Referrals	External
Lin (2001)	"investment in social relations with expected returns in the marketplace" (p.19)	Access to Resources	External
Nahapiet & Goshal (1998)	"the sum of the actual and potential resources embedded within, available through, and derived from the network of relationships possessed by an individual or social unit" (p. 243)	Access to Resources	Both
Adler & Kwon (2002)	"The goodwill available to individuals or groups. Its source lies in the structure and content of the actor's social relations. Its effects flow from the information, influence and solidarity it makes available to others" (p. 23).	Enhanced access to information Improved information quality, relevance timeliness Increased influence, control, power Solidarity of the social network	Both

Thus, investments in and returns from social capital can be seen as separate and distinct from other capital investments. While social capital is distinct from human capital, it has been recognized as being contextually complementary. Social capital predicts that human capital investments such as intelligence and seniority, and their returns depend to some degree on the location of the person in a particular hierarchy's social structure (Burt, 1997). Relating this definition to the IS leader role and context the goal of cooperative action is the focus of this paper. Like a chief executive officer (CEO), the top IS leader has responsibility of successfully enabling processes across functions, departments and geography. However, unlike the CEO, the top IS leader might not have direct authority over the management involved with using the information technology. Therefore, strengthening and maintaining the social capital that makes cooperative action possible becomes important.

Origins of Social Capital

There have been multiple origins of social capital presented in literature. Portes (1998) provides one view of history in his discussion of the origins of social capital and its applications in the field of sociology. Portes (1998) credits Bourdieu (1985) with the first systematic contemporary approach and makes mention of Loury (1977, 1981) as a second source that was extended by Coleman (1988). Bourdieu (1985) defines the concept as “the aggregate of the actual or potential resources which are linked to possession of a durable network of more or less institutionalized relationships of mutual acquaintance or recognition” (p. 248). This approach to social capital is based on the social relationship that gives individuals access to resources which other individuals possess and acknowledges differentials in the quantity and quality of those resources (Portes, 1998).

Loury (1977, 1981) applied the term social capital as part of his critique of racial income inequality as a basis for explaining the lack of network and information about job opportunities for a young black workers in the labor market which helped to perpetuate racial inequality (Portes, 1998). According to Portes (1998), Coleman (1988) extended Loury’s brief acknowledgment of social capital, explicating the role of social capital in the creation of human capital.

Coleman’s conceptualization of social capital started with Granovetter’s (1973) strength of weak tie (SWT) theory. Granovetter presented the concept of a distinction between the strong ties of a social clique and the weak ties of acquaintances or contacts that reach outside one’s close social network. He showed that in a job search better information came from the weak ties than the strong ties. This was due to the differences in information sharing processes between the two groups. Strong tie groups are dense, making it more likely that new information is shared quickly and information redundancy is highly likely, whereas weak ties are interconnections between the strong tie groups which provide intermittent unique information. This view introduced the importance of networking to produce relevant, perhaps critical resources in the form of new, sometimes unique information.

Another approach to social capital is Burt’s (1997) structural hole theory which “describes how social capital is a function of brokerage opportunities in a network” (p.339). The theory is based on the concept that some people act as brokers of information as they are connected to individuals that others are not connected to. Between the people that are not connected there is a hole in the social structure. The people that can bridge the hole act as brokers. The position of the people that act as brokers can be an asset in and of itself, called social capital. Here, social capital is defined “in terms of the information and control advantages of being the broker in relations between people otherwise disconnected in social structure…[and]

an opportunity to … control the form of projects that bring together people from opposite sides of the hole" (Burt, 1997, p.340).

A third major theoretical origin of social capital is known as the social resources theory (Lin et al., 1981) which focused on the social resources that are part of the individual's network. They defined social resources as "the wealth, status, power as well as social ties of those persons who are directly or indirectly linked to the individual" (Lin et al., 1981). Two components of social resources are identified. They are social relations, which are delineated by social control processes as defined by Goode (1978) such as friendship, love, affection, and the resources embedded in positions reached through the social relations. The emphasis here is on the resources that can be reached through the social ties such that the individual is more likely to reach someone with the resources needed to obtain a particular objective (Seibert et al., 2001).

Focus of Conceptualization

There are two opposing, yet complementary foci underlying social capital – internal versus external. The internal focus is primarily concerned with the relationships that an individual maintains with other individuals and the resources available within the network established. With the internal focus density is a key attribute of the network. Coleman (1990) exemplifies this view, emphasizing the collectivity of the network that will facilitate the collective goals, which has been termed the "bonding: forms of social capital (Adler & Kwon, 2002). The external focus illuminates the span of relations in the network, looking at those resources that an individual would not be able to reach by themselves without a "bridge", i. e. another individual with the connection to those resources (Adler & Kwon, 2002). Following the external focus Burt (1997), Bourdieu (1985), and Lin (1981, 2001) look to outward access of resources through a social network. Since these foci are not mutually exclusive and to a large degree dependent on the perspective and level of analysis, there are approaches that utilize both views (Adler & Kwon, 2002). Nahapiet and Goshal (1998) approach social capital utilizing this duality to develop a theory of social capital creation and its impact on intellectual capital development.

Levels of Analysis

In addition to the many theoretical approaches to social capital there is the dimension of level of analysis that varies among models. Social capital has been used to describe worldwide strategy application, organizational or collective application and individual level application. In a worldwide application social capital has been leveraged and used for a poverty reduction strategy (Grootaert & Van Bastelaer, 2002). In organizational use social capital may focus on concerns such as employment practices (Leana and Van Buren III, 1999), intrafirm resource exchange (Tsai & Goshal, 1998), or the creation of intellectual capital (Nahapiet & Goshal, 1998). Applying social capital concepts at the individual level has included career success (Podolny & Baron, 1997; Seibert et al., 2001), workers finding jobs (Granovetter, 1973), and executive compensation (Belliveau, O'Reilly, & Wade, 1996). Leana and Van Buren III (1999) note that the multilevel nature of social capital has lead to two patterns emerging, public goods and private goods. When the focus is on public goods researchers concentrate on the macro level and the micro or individual level is secondary. Thus, social capital is considered more of a social unit attribute whereby the benefits and costs accrue to the social unit and the individual is only indirectly involved. When the private goods focus is used the benefits and costs become individual advantages, leading to such outcomes as higher career success. Although social capital is multilevel, it is considered to be a resource that is jointly owned and therefore some models, such as the organizational social capital model, may include both the public good and private good perspective (Leana & Van Buren III, 1999). Interestingly, it has been noted recently that there is an imbalance in the social capital research for information and communication technologies relative to levels of analysis with the majority of research being at the collective level (Yang, Lee & Kurnia, 2009). This paper's focus on the IT leadership provides an individual level of analysis framework that has been neglected to date.

Benefits of Social Capital

Like the concept of social capital, there are multiple perspectives of its benefits. In this model the goal is to have success with IT investments, therefore both foci – internal and external – are included.

Social capital, as defined by Coleman (1990), is internally focused, standing for any part of a social structure that creates value and facilitates the actions of the individuals within that social structure. Its elementary foundation includes the creation of obligations and expectations, potential for enhanced information acquisition and the transfer of authority or rights of control (Coleman, 1990). In particular, the transfer of authority or rights of control to an IS leader could help to span the organizational hierarchy when dealing with the IT investment in various functions outside their formal line of authority.

Burt (1997) utilizes an external focus identifying three benefits of information exchange for a manager – access, timing and referrals. Access refers to the information through the network that could not be otherwise gained because the source of the information is beyond the direct reach of a manager. Timing is the advantage of receiving the information earlier through a network than a manager would receive through a direct contact. Referrals deal with the benefit of legitimizing the interests of a manager as the information is presented "in a positive light, at the right time, and in the right places" (p. 340). The action of legitimizing through social capital is particularly important for the IS leader as they are frequently responsible for IT throughout the corporation (Applegate & Elam, 1992), but typically do not have authoritative control throughout the corporation. This dimension echoes the benefits derived from the transfer of authority or rights of control identified by Coleman (1990), as previously discussed.

Social capital is like the more tangible financial and physical capital in that it can be "demonstrated, analyzed, invested in, worked with and made to yield benefits" (Cohen & Prusak, 2001, p.9). Like the other forms of capital it "accumulates when used productively" (Fountain, 1998). Unlike the other intangible forms of capital known as human capital and intellectual capital, social capital may have an advantage in the way it accumulates. Lin (2001) posits that social capital is accumulated exponentially, whereas human capital is considered to be additive. This occurs because social capital is derived through relational ties with another individual would give access to the other individual's ties in addition to the direct relation. In addition to specific advantages of social capital, Adler and Kwon (2002) propose the benefits to include: 1.Enhanced access to information and improved information quality, relevance, and timeliness; 2.Increased influence, control and power; and 3.Solidarity of the social network. These benefits could be used to support the goal of leveraging the IT investments. Understanding the structures of the social capital investment in relationship to IT would provide a foundation for working with and developing the benefits of social capital.

IS Leadership and Social Capital

When the term Chief Information Officer (CIO) was first introduced by Synott and Gruber (1981) it was recognized that "the role of the information systems manager has evolved in twenty years from that of a technician managing a relatively unimportant service function into that of a vice presidential-level, general manager whose department can substantially impact the entire organization" (Ives & Olson, 1981, p. 49). That role continues to evolve and grow as the needs of businesses change. One view of the CIO's function is as a bridge over the gap between an organization's strategy and its use of IT (Stephens, Ledbetter, Mitra & Ford, 1992). Acting as a bridge between IT, the functional areas and external areas (Stephens et al., 1992) exemplifies the social capital brokerage function that is the foundation of Burt's (1997) structural hole theory. The function is fulfilled, in part, when the CIO is an active participant in the organization's strategy planning (Stephens et al., 1992).

For an IS leader to be effective, it has been suggested that they must be very aggressive in establishing and maintaining a large network of resources (Applegate & Elam, 1992). Success factors for IT have been proposed to include relationship building and partnering with business users (Applegate & Elam, 1992; Willcocks & Stykes, 2000; Bharadwaj, 2000; Ross et al., 1996), communication with top management, functional managers and end users (Passino & Severance, 1988), managerial IT skills including the ability to work with functional managers, suppliers, and customers (Mata et al., 1995), the Chief Information Officer's (CIO's) participation in the top management team (Armstrong & Sambamurthy,1999) and the "system of knowing" for the Chief

Financial Officer (CFO) and top management team (Armstrong & Sambamurthy, 1999). These success factors are all based on social relations, i.e. the creation of social capital.

Mata et al. (1995) elaborated on the specifics of important IT managerial skills as the ability to understand and appreciate, work with, support and anticipate the future needs of functional managers, suppliers and customers. "That these managerial skills are valuable is almost self-evident. Without them, the full potential of IT for a firm will almost certainly not be realized" (Mata et al., 1995). Armstrong and Sambamurthy (1999) proposed that the quality of senior leadership, including the Chief Information Officer (CIO) the Chief Executive Officer (CEO), the Chief Operating Officer (COO), and the Chief Financial Officer (CFO), and their interactions were the fundamental factors influencing the IT assimilation form of IT success. Armstrong and Sambamurthy (1999) operationalized quality for the CIO as their level of business knowledge, IT knowledge and "systems of knowing". The "systems of knowing" refers to the structures of interaction among team members. The structures of interaction may take the form of hierarchical distance of the CIO from the CEO (Feeny, Edwards & Simpson, 1992; Watson, 1990) or the extent of the CIO's participation in the senior management team (Watson, 1990). Keen (1991) suggested that "dialogue is needed most right at the top of the firm. It is no exaggeration to say nothing will contribute more to a firm's ability to take charge of change related to or fueled by IT than to have the firm's business and IS leaders make the issues of economics and integration a mutual priority" (p. 219). Similarly, Nahapiet and Goshal (1998) propose that social capital facilitates the creation of new intellectual capital which leads to an organizational advantage of firms over markets.

The very nature of IT as a potentially boundariless resource acting as a conduit for information to flow between functions and levels in an organization makes its leading manager a unique and significant user of the social capital asset. The significance comes from the ubiquity of IT (Carr, 2003), the uniqueness comes from the cross-functional nature of the IT asset and its management. Both of these dimensions pose issues for the IT leader to overcome. For example, if territorial senior executives perceive a threat from IT in their domain, they may become obstacles for innovation (Feeny et al., 1992). Lind and Zmud (1991) discovered that rich interaction among technical and managerial personnel counteracted obstacles to innovation. Thus, it appears social interaction, i.e. creation of social capital, is a significant enabler for the IT leader to successfully traverse the organizational landscape.

As IT has changed from a support data processing function to a critical component for achieving corporate strategic objectives, the role of the IS leader has changed. The IS leader, who was traditionally weak in establishing networks, is being called upon to understand their organization's strategic objectives and to effectively interact with corporate/business management to ensure that IT investments are aligned appropriately (Applegate & Elam, 1992).

PROPOSED FRAMEWORK AND PROPOSITIONS

Seibert, Kraimer & Liden (2001) introduced a model for social capital theory of career success that looked at the effects of social resources and network benefits on the outcome of career success with the social resources antecedents of network structure dimensions (See Figure 1). The model suggests that the outcome of the success of information technology can be looked at as career success for an organization's IS leader. Thus, application of the model, with modifications for the specifics of the research areas of interest is proposed (see Figure 2).

Figure 1: Hypothesized Model of Social Capital Effects on Career Success (Seibert et al., 2001)

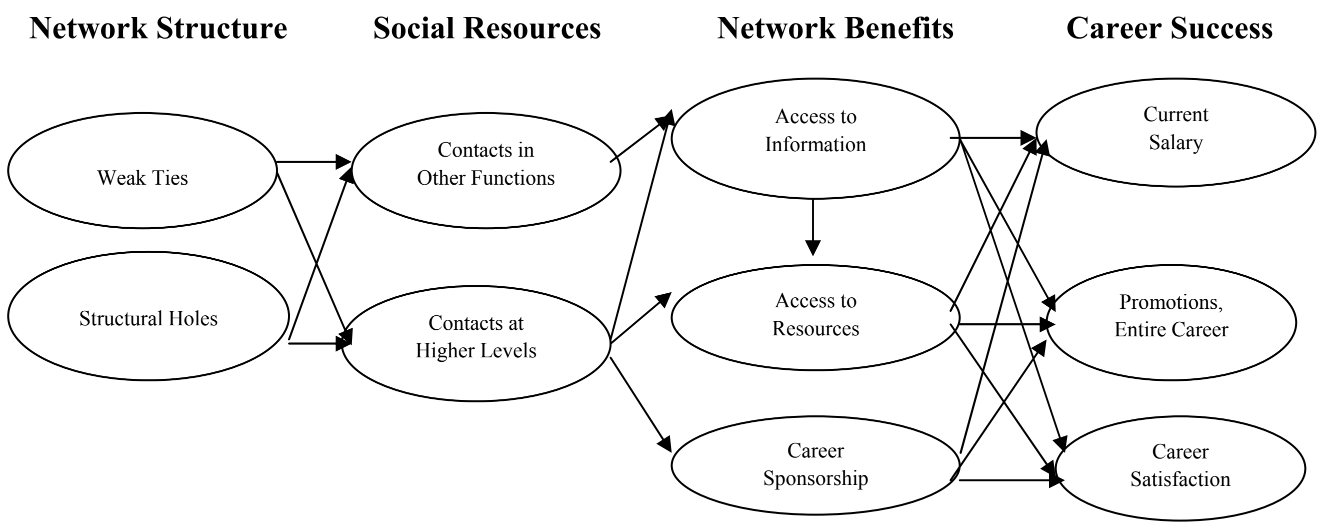
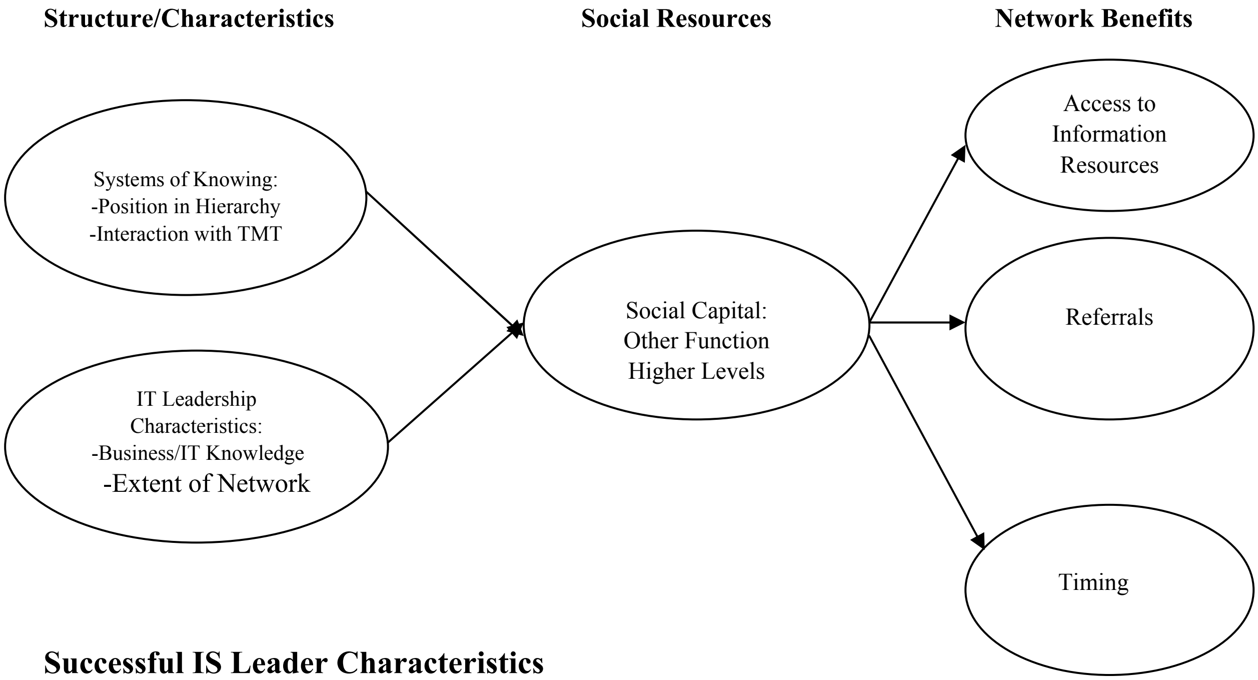


Figure 2: Proposed Conceptual Model



Successful IS Leader Characteristics

In the 'information era' of the 1990s [and beyond], a new and expanded set of responsibilities demands that the executive responsible for IT throughout the corporation also possess strong leadership skill, power, and business expertise" (Applegate & Elam, 1992). IT has grown in power and ubiquity, causing many companies to view it as more critical than ever regarding their success (Carr, 2003). While investments in IT have grown significantly, there is still a wide range of outcomes for how successful firms are at leveraging the business value of IT, making the impact of the top IS leader's business and IT knowledge more evident than ever before. "CIOs with high levels of business and IT knowledge will be perceived as valuable players and be more easily accepted by the top management team" (Armstrong & Sambamurthy, 1999, p.308). The CIO has been considered to be the bridge in the organizational structure with participation in the strategic planning meetings being a key establishing and maintaining that bridge (Stephens et al., 1992). The operationalization of the quality of IS leadership has included measures of their IT and business level knowledge, the informal interactions of the CIO with the senior management (Armstrong & Sambamurthy, 1999), and the extent of participation in top management including strategic planning meetings (Armstrong & Sambamurthy, 1999; Stephens et al., 1992).

The recognition of the top IS leader's integral importance in the firm and the strategic importance of the success of IT initiatives leads to the following proposition.

P1: The leadership characteristics exhibited by the top IS leader in an organization will have a significant impact on the development of the leader's social capital.

Hierarchical Positioning

"Hierarchy is an important dimension of social structure that indirectly influences social capital by shaping the structure of social relations" (Adler & Kwon, 2002). These social relations come in the form of interaction, formal and informal, and knowledge sharing. Interaction between the top IS leader, often named the chief information officer (CIO), and senior business executives resulting in strong partnerships have been found to positively affect key IT project success processes such as IT assimilation (Armstrong and Sambamurthy, 1999). Various leadership styles, such as transactional and transformational, are viewed as relying on the leader's authority or position of power. The importance of the relationship is based on the argument that "IT successes generally reflect an effective relationship between business managers and Information Services managers and their staffs" (Keen, 1991, p.215). Knowledge sharing can be accomplished *objective knowledge* which describes explicit knowledge that each individual team member has and *systems of knowing* that describe the shared perspectives and sharing of understanding (Nahapiet & Goshal, 1998). It is the systems of knowing that are related to the hierarchical positioning of the CIO in terms of the distance from the CEO in the hierarchy and the amount of the CIO's participation in the top management team (Watson, 1990). The strong partnership between the CEO and CIO in terms of interaction was found to enable the sharing of ideas and understanding of strategic business and IT issues (Armstrong & Sambamurthy, 1999), contribute to increased levels of IT innovativeness (Lind & Zmud, 1991) and influence the firms' use of IT (Jarvenpaa & Ives, 1991). The hierarchical structure, as related to the social structure, is also important in terms of access to valuable resources, since "the higher positions have more information about the locations of valued resources in the hierarchy – where specific types and amounts of resources are embedded" (Lin, 2001).

Top management or senior leadership has been defined as "the CEO, COO, CIO and other senior business executives who are formal members of the top management team" (Armstrong & Sambamurthy, 1999). An individual's vertical location in the authority hierarchy will determine their access to valued resources and define their relative rank ordering in the overall chain of command (Lin, 2001). The importance of the partnership between the CIO and the top management team in terms of access to information and strategic success of IT investments leads to the following propositions.

P2a: The CIO's system of knowing in terms of the extent of their participation in the top management team will have a positive relationship with the CIO's development of social capital.

P2b: The CIO's system of knowing in terms of their hierarchical position within an organization will have a significant effect on the CIO's development of social capital.

Outcomes of Social Capital Influences

As previously reviewed, the structural hole theory proposes that there are three information benefits from social capital: access to information and resources, advantageous timing to that information and/or resource and referrals (Burt, 1997). Lin (2001) defined a simple formal structure as "a hierarchical structure consisting of a set of positions linked in authority (legitimately coercive) relations (command chains) over the control and use of certain valued resources" (p.35). Thus, it is proposed that linking the two concepts results in the following propositions.

P3a: The amount of social capital available to the CIO based on the position of the CIO relative to the top management team will significantly affect the CIO's access to valued information and resources.

P3b: The amount of social capital available to the CIO based on the position of the CIO relative to the top management team will significantly affect the CIO's referral network.

P3c: The amount of social capital available to the CIO based on the position of the CIO relative to the top management team will significantly affect the CIO's timing of valued information.

CONCLUSION

IT managerial skills and a strong partnership between the IS leader and top management are two factors that have been identified as contributing to the success of an organization. The implied importance of these factors suggest value in understanding how they contribute to success so that academics can understand and practitioners can know how to leverage the IT investment. Social capital is a relatively new, yet recognizably important concept in the social science disciplines (Adler & Kwon, 2002) and a potentially critical component in the explanation of why some organizations are successful at implementing and leveraging their IT investments and others are not.

This research contributes to theory with the proposal of a framework for studying social capital at an individual level, a level which is recognized as a significant but under researched view (Yang et al., 2009).

The implications of this research for practice are threefold. First, the identification of specific characteristics of successful IS leaders provides organizational management insight into what areas to support to maximize IS effectiveness. Second, organizations can use the framework to compare candidates for the CIO position knowing specific areas that contribute to organizational success. Finally, a framework for the intangible asset social capital gives practitioners a foundation for developing metrics to quantify the asset.

Future research with this model is planned using a survey instrument that is being developed. Other avenues of research being investigated include using secondary data to analyze the constructs and their relationships. An example of such an approach can be found in recent social capital research (e.g. Pil & Leana, 2009).

REFERENCES

Adler, P. & Kwon, S. (2002). Social capital: Prospects for a new concept. *Academy of Management Review,* 27(1), 17-40.

Applegate, L. & Elam, J. (1992). New information systems leaders: A changing role in a changing world. *MIS Quarterly*, 16(4), 469-491.

Armstrong, C. & Sambamurthy, V. (1999). Information technology assimilation in firms: The influence of senior leadership and IT infrastructures. *Information Systems Research*, 10(4), 304-327.

Bednarz, A. (2010). Outlook 2010. *Network World*, 27(1), 12-18.

Belliveau, M., O'Reilly, C., & Wade, J. (1996). Social capital at the top: Effects of social similarity and status on CEO compensation. *Academy of Management Journal*, 39(6), 1568-1593.

Bharadwaj, A. (2000). A resource-based perspective on information technology capability and firm performance: An empirical investigation. *MIS Quarterly,* 24(1), 169-197.

Bourdieu, p. (1985). The forms of capital. In J.G. Richardson (Ed.), *Handbook of Theory and Research for the Sociology of Education*, (pp.241-258). New York, Greenwood.

Burt, R. (1997). The contingent value of social capital. *Administrative Science Quarterly,* 42(2), 339-365.

Carr, N. (2003). IT doesn't matter. *Harvard Business Review,* 81(5), 41.

Cohen, D. & Prusak, L. (2001). *In good company: How social capital makes organizations work*. Boston: Harvard Business Press.

Coleman, J. (1988). Social capital in the creation of human capital. *American Journal of Sociology,* 94, S95-S120.

Feeny, D., Edwards, B., & Simpson, K. (1992). Understanding the CEO/CIO relationship. *MIS Quarterly,* 16, 435-448.

Flap, H. & DeGraff, N. (1989). Social capital and attained occupational status. *Journal of Sociology,* 22, 145-161.

Fountain, J. (1998). Social capital: key enabler, In Lewis Branscomb and James Keller (Eds.), *Investing in innovation*. Cambridge, MA, MIT Press.

Goode, W. (1978). *The celebration of Heroes*. Berkeley: University of California Press.

Granovetter, M. (1973). "The Strength of Weak Ties." *The American Journal of Sociology,* 78(6), 1360-1380.

Grootaert, C. & Van Bastelaer, T. (2001). *Understanding and measuring social capital: A multidisciplinary tool for practitioners,* Washington, D.C.: The World Bank.

Ives, B. & Olson, M. (1981). Manager or technician? The nature of the information systems manager's job." *MIS Quarterly,* 5(4), 49-63.

Jarvenpaa, S. & Ives, B. (1991). Executive involvement and participation in the management of information technology" *MIS Quarterly,* 15, 205-227.

Keen, P.G.W. (1991). *Shaping the future.* Harvard Business School Press, Boston, MA.
Leana, C. & Van Buren III, H. (1999). Organizational social capital and employment practices. *The Academy of Management Review,* 24(3), 538-555.
Lin, N. (2001). *Social capital: A theory of social structure and action.* Cambridge University Press, NY, NY.
Lind, M. & Zmud, R. (1991). The influence of a convergence in understanding between technology providers and users on information technology innovativeness. *Organization Science*, 2,195-217.
Loury, G. (1977). A dynamic theory of racial income differences. In P.A. Wallace & A.M. La Mond (Eds.) *Women, Minorities, and Employment Discrimination* (pp.153-86).Lexington, MA: Heath.
Loury, G. (1981) Intergenerational transfers and the distribution of earnings. *Econometrica,* 49, 843-67.
Mata, F., Fuerst, W., & Barney, J. (1995). Information technology and sustained competitive advantage: A resource-based analysis." *MIS Quarterly*, December, 487-506.
Nahapiet, J. & Ghoshal, S. (1998). Social capital, intellectual capital, and the organizational advantage." *Academy of Management Review,* 23(2), p.242-268.
Passino, J. & Severance, D. (1988). The changing role of the chief information officer. *Strategy & Leadership*, 16(5), 38-43.
Pil, F. & Leana, C. (2009). Applying organizational research to public school reform: The effects of teacher human and social capital on student performance, *Academy of Management Journal*, 52(6), 1101-1124.
Podolny, J., & Baron, J. (1997). Resources and relationships: Social networks and mobility in the workplace. *American Sociological Review,* 62, 673-693.
Portes, A. (1998). SOCIAL CAPITAL: Its origins and applications in modern sociology. *Annual Review of Sociology,* 24,1-24.
Ross, J., Beath, C., & Goodhue, D. (1996). Develop long-term competitiveness through information technology assets. *Sloan Management Review*, Fall 1996, 38(1), 31-49.
Seibert, S. Kraimer, M. & Liden, R. (2001). A social capital theory of career success. *Academy of Management Journal,* 44(2), 219-237.
Stephens, C. Ledbetter, W. Mitra, & A, Ford, F. (1992). Executive or functional manager? The nature of the CIO's job." *MIS Quarterly,* 16(4), 449-468.
Synott, W. & Gruber, W. (1981). *Information Resources Management.* John Wiley & Sons, New York, NY.
Tsai, W. & Ghosal, S. (1998). Social capital and value creation: The role of intrafirm networks. *Academy of Management Journal,* 41, 464-478.
Watson, R. (1990). Influences on the IS manager's perception's of key issues: Information scanning and the relationship with the CEO." *MIS Quarterly,* (June), 217-231.
Willcocks, L. & Stykes, R. (2000). The role of CIO and IT function in ERP. *Communications of the ACM*, 43(3), 32-39.
Yang, S., Lee, H., & Kurnia, S. (2009). Social capital in information and communications research: Past, present and future. *Communication of the Association for Information System,* 25, 183-220.

U.S. MOBILE TV ADOPTION STRATEGY: IS IT CONSUMER CHOICE?

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ABSTRACT

Although Mobile TV has yet to penetrate the U.S. market with a substantial number of subscribers, it is "the" issue of concern for consumers in eastern Asia and Europe. Several reasons for the slow adoption of Mobile TV in the U.S. market exist including culture, consumer choice, content providers, and most surprisingly, technology commitments by major network operators. However, given the global interest in the technology, the U.S. Market will follow suit but only after a number of trials are successfully tested throughout the country. A U.S. Mobile TV market analysis is given using an overview of recent survey data about potential U.S. users' perceptions of Mobile TV.

INTRODUCTION

Mobile TV is fast becoming a technology that will compliment the mobile data services already available on cell phones today. There are several competing technology standards in the world: Digital Multimedia Broadcasting (DMB) in Korea, Digital Video Broadcasting (DVB) in Europe, Integrated Services Digital Broadcasting (ISDB) in Japan, China Mobile Multimedia Broadcasting (CMMB) in China, and MediaFLO (Forward Link Only) in U.S. Among them, Korea began its mobile TV services in 2005 and the size of their market is the largest in terms of number of subscribers (19 million subscribers in 2009).

There are two main technologies in the development of mobile TV. One of them is terrestrial technology, which uses existing cellular/broadcasting networks for mobile broadcasting, and the other is satellite technology. DMB in Korea uses both technologies: T-DMB (terrestrial) and S-DMB (satellite). S-DMB uses a Ku-band (13.824-13.849 GHz. for uplink and 12.214-12.239 GHz for downlink) and an S-band (2.605-2.655 GHz from satellite and gap-filler to a mobile TV cellular phone), while T-DMB deploys a broadcasting network employing unused VHF channels (174-216 MHz). DVB in Europe has also two platforms for its mobile TV service, DVB-T (terrestrial) and DVB-SH (satellite). In July 2007, The European Commission endorsed a Nokia-backed mobile TV standard called DVB-H, stating that Europe needed to pick one technology over others and promised to look at ways to mandate its use. Japan was the first country to broadcast TV to automobiles through a satellite. Its terrestrial version (ISDB-T) started its service in 2006 under the name of 1Seg (One Seg). Within the

United States Market, there are two competing technologies, MediaFLO (Forward Link Only) and DVB-H. MediaFLO is Qualcomm's new technology to broadcast video to cellular phones. The U.S. major cellular network operators are only now positioning themselves for the inevitable battle that will ensue over the lucrative business opportunities that Mobile TV will provide.

BACKGROUND OF MOBILE TV TECHNOLOGIES

As we mentioned earlier, terrestrial and satellite are the two platforms for mobile TV technology. T-DMB, DVB-H, and MediaFLO are cellular/broadcasting network based terrestrial technologies and S-DMB, DVB-SH, and CMMB are satellite technologies. There are pros and cons of each technology. While satellite Mobile TV has a large coverage area, like nationwide, terrestrial Mobile TV has a regional, local coverage. Once the satellite for Mobile TV is launched, the Mobile TV service is available in all nations where the satellite signal reaches. But terrestrial Mobile TV is deployed city by city, where a cellular/broadcasting network infrastructure already exists. Usually, the satellite Mobile TV uses higher frequencies (S-band, 2.6 GHz) than the terrestrial Mobile TV (MediaFLO, 716-722 MHz, T-DMB 174-216 MHz). Even if DMB has been successful in Korea and ISDB-T is a major standard in Japan, DVB-H and MediaFLO are considered to be the two main competing technologies worldwide. DVB-H is the de facto standard in Europe and two of the largest wireless carriers in the US (Verizon Wireless and AT&T Mobile) chose MediaFLO as their Mobile TV technology platform. In 2007, Verizon Wireless just started Mobile TV service in the limited number of U.S. cities under the brand name of VCAST, which is a combined mobile TV service with a 3G video streaming. AT&T is planning to launch a similar service.

Technology Adoption for U.S. Mobile TV

Technology adoption by markets is a complex process that depends on factors that may or may not be under the control of a technology's advocates. The technology adoption process in mobile television is not driven by such a battle. Different standards can coexist, as is the case with 2G and 3G mobile systems in the US and the DMB providers in Korea, because the end user cares about the technology only to the extent that it affects his or her value proposition in purchasing the service (i.e., cost, quality, viewing experience, etc.). In these markets, it is possible for providers to switch from one technology to another (as was done by AT&T Mobile and Bell South Mobile when they switched from TDMA to GSM several years ago). The adoption of mobile TV technology is therefore driven by making a compelling value proposition to end users rather than the choice of the standard.

The cost drivers for mobile services are determined by spectrum costs, equipment costs, engineering costs, media costs, and marketing costs. The media costs consist of content acquisition costs and the costs of reformatting and packaging the content for mobile broadcasting. The adoption of a single standard can drive down equipment cost (both for the consumers and the service providers) and engineering costs somewhat, but the real cost factor is in the media costs because it is ongoing as opposed to up-front. If the adoption of a single standard allows media to be packaged for mobile TV once, then the costs are shared by all providers, reducing the cost basis.

In cellular technology, the US experienced a technology competition between European based technology developers, Nokia and Ericsson and U.S. based Qualcom. From 2G cellular technology to 2.5G and 3G, both parties have been in head-to-head competition. In mobile TV technology, there has been a service using an existing 3G unicast technology, which sends a video streaming signal over a 3G channel. This technology is affordable when the number of mobile TV users is few. The United States followed European's lead in adopting the open standard GSM for its cellular phone network. This is primarily because the large network operator AT&T used GSM as its technology. But in the Mobile TV situation, AT&T Mobile has surprisingly announced to go with the proprietary Qualcomm technology, MediaFLO. It is described as using a broadcast service known as the FLO network to provide shared content while also taking advantage of the 3G network to provide unique content to subscribers. Since Verizon Wireless took CDMA and CDMA2000 developed by Qualcom as 2G and 3G mobile cellular service standards, it is natural that Verizon Wireless chose MediaFLO (by Qualcom) as its Mobile TV standard. Since AT&T Mobile is committed to using the MediaFLO technology, it would probably be a safe assumption to believe that AT&T Mobile feels like MediaFLO technology is superior to the DVB-H technology or it could reduce the media cost of mobile TV service from the overall value chain systems.

User's Perception IN United States

The authors conducted a survey about potential demand for mobile TV service in the U.S. The effective respondents included professionals (non-student), upper division undergraduate students (junior and senior), and professionals with a status of graduate student, who reside in a small city (Meridian, Mississippi, population around 40,000) or a metro area (San Antonio, Texas, population over 1,000,000) of the southern region of the United States. Distribution of the respondents is that 66% are in their twenties. The following table shows distribution of respondent's age and job status.

Table 1: Distribution of Respondent's Age with Job Status

Job Status	20 - 29	30 – 39	40 – 49	50 ~	Total
Student Only	95	12	5	1	113
Student+ Professional	53	11	10	2	76
Professional Only	12	9	17	15	53
Total	160	32	32	18	242

In comparison to the RBC Capital Market's survey about Mobile TV, three quarters of their respondents in North America replied that they had no interest in watching TV using cellular phones, and 69% said that they do not see themselves using cellular phones for musical entertainment. However, since the respondents in our survey are relatively younger, their interests and propensity to use technology are remarkably different. A new media service like Mobile TV usually targets a younger generation which historically has shown to be more amenable to using new technologies. In contrast more than half of the respondents in our survey (refer to Table 2) answered that they are interested in watching TV on their cell phone, whether it is a terrestrial based or satellite based mobile TV service. We found that the younger the respondents, the higher number for Mobile TV.

Table 2: Age group and Interest in Mobile TV

Age Group	No. of Respondent	Terrestrial Based Mobile TV	Satellite Based Mobile TV
20 – 29	160	59.4%	56.3%
30 – 39	32	46.9%	50.0%
40 – 49	32	43.8%	46.9%
50 ~	18	17.8%	22.2%
Total	242	52.5%	51.7%

Since 84.1% of the student only group respondents are in their twenties, which is a much higher percentage of twenties than in the other groups, the student only group's Mobile TV preference is higher than those of other groups (Table 3) and there is no significant difference of Mobile TV preference between small city and metro area (Table 4).

Table 3: Mobile TV Preference with Job Status

Job	Terrestrial Based Mobile TV	Satellite Based Mobile TV
Student Only	62.7	63.9
Student + Professional	40.8	40.8
Professional Only	44.9	42.9

Table 4: Mobile TV Preference with a Region

Job	Terrestrial Based Mobile TV	Satellite Based Mobile TV
Small City	.516	.485
Metro Area	.563	.449

Table 5 and table 6 show respondents' willingness-to-pay for a Mobile TV enabled cellular phone and a monthly Mobile TV subscription rate. More than 50% of respondents are willing to pay $100 for a Mobile TV enabled cellular phone and $10 - $20 per month for the Mobile TV service. There is no significant difference in willingness-to-pay between students and professionals. The importance of this finding is that students and professionals face many of the same environmental factors but also have many of the same goals. Theoretically, the primary factor would be busy lifestyle and the goal would be to find a balance between work and pleasure. In table 7, there is a list of content categories respondents want to watch in their cellular phone. News and weather are the top two favorite contents and entertainment, movie, and music video are the next group of contents.

Table 5: Distribution for Willingness-to-pay for Mobile TV cellular phone

Price	$100	$200	$300	$400	$500	$600	Mean
Percentage	51%	26%	16%	3%	2%	1%	$184

Table 6: Distribution for Willingness-to-pay for Mobile TV Monthly Service

Price	$10	$20	$30	$40	$50	$60	Mean
Percentage	32%	26%	21%	9%	5%	6%	$25

Table 7: Mobile TV Content Preference

Contents	News	Weather	Entertainment	Movie	Music Video
Percentage	65.8%	49.4%	39.7%	36.2%	30.7%
Contents	Sports	Education	Drama	Shopping	Adult
Percentage	28.4%	12.8%	12.5%	6.2%	3.5%

Further research in this area is justified in that it could address the issues of environmental factors and group goals in more detail. Speculatively, it could be because of busy lifestyles, or it is the way this generation has found to stay connected with their world. The entertainment value just adds convenience and utility to a tool they are already using daily.

CONCLUSION

According to the Cellular Telecommunications & Internet Association's (CTIA) wireless industry, at the time of June 2010, the estimated number of U.S. mobile subscribers was over 293 millions, which means a penetration ratio of mobile service is 97.6% with an assumption of 300 million U.S. population. This means that the wireless voice market is almost saturated and wireless carriers are trying to extend their services to new areas such as 3G and/or other additional value-added services like Mobile TV.

From a broadcasting perspective, the Mobile TV market in the United States is only in its infancy. However, the technology is being developed behind the scences to the point that Mobile TV could be a common house-hold word in less than five years. The U.S. will benefit from the improvements made in rest-of-world (ROW) markets. This will accelerate the adoption process so that once the crtical mass decision point is reached, the roll out of the appropriate technology will be very quick and costs should be even more competitive. The technology demanded by ROW is definitely growing in momentum. The competitive forces that will shape the Mobile TV market allows for a profitable industry given that there are few/weak competitive forces in the supplier's bargaining power and low threats from new entrants in the market. The steps along the value chain still need to be developed within the United States in order to meet the demands of potential Mobile TV customers.

New services like mobile TV require significant investment, flexibility in technology choice, and innovative management skills. Since mobile TV represents a convergence in technologies between cellular phone and mobile TV, it will also create market niches (pay per view, etc.) and challenges (competing technologies and services). Through the survey of potential customers taken from different regions of the country, we found that the average price consumers are willing-to-pay for mobile TV is close to $25. Interestingly, in our survey we found there was no difference between student and professional groups. Based on the output of the survey, U.S. consumers are interested in the Mobile TV service. Value to both professionals and students is similar to what one would expect to pay for the most basic cable or home-based satellite service.

The cellular television mobile service industry is complex. These complexities span technical, logistical, social, and cultural factors. Cooperation is essential among the cellular and network service providers, service developers, and equipment makers, to collaborate with governments, policy makers, and users if they are to create a growth market in the mobile TV telecommunication industry in America. History is replete with examples of other industries trying to work with content providers and this one difficulty could determine the long term success or failure of the cellular TV concept. The authors also believe that the findings from this research contribute towards the understanding of the pricing and distribution model for the roll-out to the American audience.

REFERENCES

Lee, S. and Kwak, D., (2005), TV in Your Cell Phone: The Introduction of Digital Multimedia Broadcasting (DMB) in Korea, *Proceeding of the TPRC 2005 conference*.

Shim, J., Shin, S., and Weiss, M, (2007) Digital Multimedia Broadcasting (DMB): Standards, Competition, and Regulation in South Korea, *Journal of Information Technology Theory and Application*, Vol. 8, No. 2, pp 69-81.

CONTINUOUSLY INCREASING PRICE IN A GRADUAL USAGE INVENTORY CYCLE: AN OPTIMAL STRATEGY FOR COORDINATING PRODUCTION WITH PRICING FOR A SUPPLY CHAIN

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ABSTRACT

Inventory control literature has always assumed that when using the EOQ model, a retailer would find it optimal to sell the product at a fixed price even in the event of planned gradual usage (or gradual production). We present a model that shows when the inventory is price sensitive, a retailer is better off using a continuously increasing price strategy than using a fixed price strategy within each inventory cycle. The model is particularly applicable for supply chain when price elasticity changes and a retailer have to revise the corresponding inventory policy accordingly and timely as market condition dictates.

Key words: Inventory, Gradual Usage, Price Elasticity, Supply Chain.

INTRODUCTION

The inventory literature has received attention in manufacturing industry almost a century ago. In 1913, Ford Harris suggested an idea of how many parts to make in a batch. The Harris order batching model has then been forgotten until the idea was later published by Wilson (1934) in *Harvard Business Review.* The batching rule then became known as the Wilson Economic Order Quantity (EOQ) as it applies to inventory management.

The model assumes that a retailer of a product buys the product at a constant unit cost, incurs a fixed cost per order, stores the product at a constant carrying cost per unit of inventory per year, and faces a deterministic and constant demand rate over an infinite horizon, the retailer's optimal strategy is to buy a fixed quantity every time he or she replenishes the inventory. Ignoring inventory related costs, classical price theory tells us that when a product's demand is price sensitive but the demand curve is known and stationary, the retailer's optimal strategy is to charge a single price throughout the year. Although Whitin (1955) was the first one to integrate the concepts of inventory theory with the concepts of price theory to investigate the simultaneous determination of price and order quantity decisions of a retailer, he never stated so explicitly. Whitin's (1955) model would adhere to all the assumptions of the EOQ model stated above, except that demand is price sensitive, with a known and stationary demand curve, a retailer's optimal strategy would be, once again, to buy a fixed quantity for every inventory cycle and to sell it at a single price.

Kunreuther and Richard(1971) then showed that when demand is price elastic, centralized decision-making (using simultaneous determination of optimal price and order quantity) was superior to the common practice of decentralized decision-making whereby the pricing decisions were made by the marketing department while the order quantity decisions were made by the purchasing department independently. Although Kunreuther and Richard (1971) were perhaps unaware of Whitin's (1955) paper, their model was very similar to Whitin's (1955) model. Assuming a known and stationary demand curve along with the remaining conditions of the EOQ model, Arcelus et al (1987, page 173) asserted: "given constant marginal costs of holding and purchasing the goods, the firm will want to maintain the same price throughout the year". Again, they assumed a fixed single selling price throughout each inventory cycle. What they did not realize is that, even though marginal holding costs are constant per unit, a firm's holding costs at any particular time within an inventory cycle are a function of inventory on hand, which itself is a function of the time from the beginning of the inventory cycle.

Since Whitin's (1955) work, numerous authors (Tersine & Price,1981; Arcelus & Srinivasan,1987; Ardalan, 1991; Hall, 1992; Martin, 1994; Arcelus & Srinivasan, 1998; Abad, 2003) have used Whitin's (1955) and Kunreuther and Richard's(1971) models as foundations to their own models. But none of these authors have ever questioned Whitin's (1955) and Kunreuther and Richard's (1971) assumption that the retailer's optimal strategy would be to sell the product at a fixed price throughout the inventory cycle. The fact that Whitin's (1955) and Kunreuther and Richard's (1971) assumption of a single price throughout an inventory cycle leads to suboptimal profits for the retailer is due to declining carrying costs as a function of time. However, any optimization model allowing a retailer with a price-insensitive demand to set the selling price arbitrarily would push the price to infinity. In other words, in that situation, price is not seen as a decision variable for any mathematical model. Given an arbitrary price (and corresponding demand), the retailer's only strategy is to minimize his inventory ordering and holding costs by using the EOQ model.

Considering a situation of price sensitive demand, Abad (1997; 2003) found that, in the case of a temporary sale with a forward buying opportunity, a retailer's optimal strategy is to charge two different prices during the last inventory cycle of the quantity bought on sale—a low price at the beginning of the inventory cycle and a higher price starting somewhere in the middle of the cycle. Yet, Abad (1997; 2003) did not consider a similar strategy in every regular inventory cycle of a product with price sensitive demand. Inspired by Abad's (1997; 2003), Joglekar et al (2008) showed that a continuously increasing price strategy: charging a relatively low selling price at the beginning of an inventory cycle when the on-hand inventory is large, would lead to higher profit.

With the widespread use of revenue management or yield management techniques (Feng & Xiao, 2000; McGill &. van Ryzin,1999; Smith, Leimkuhler & Darrow, 1992; Talluri & van Ryzin,2000; Weatherford &. Bodily, 1992. in the airline, car rental, and hotel industries today, a time-dependent (or dynamic) pricing strategy has become commonly adopted. Revenue management techniques are typically applied in situations of fixed, perishable capacity and a possibility of market segmentation (Talluri & van Ryzin, 2000). In recent years, retail and other industries have begun to use dynamic pricing policies in view of their inventory considerations. The recent recession has brought forth dynamic pricing to a new light. As retail sales dropped, businesses were facing unusual built-ups of inventory that would lead to order cancellations affecting all parties of the supply chain.

In this paper, we extend the dynamic pricing model to incorporate the gradual usage (or gradual production/ replenishing) inventory. (See Chase et al, 2010) for the gradual usage model.) Consider a retailer that is also a manufacturer of a product. Depending on the demand and the ordering quantity, the retailer would produce the inventory gradually until it fulfills the planned order quantity. Since the build-up is gradual, the actual inventory holding cost will be lowered and that the maximum inventory level will not be as high as the basic EOQ. In light of the currently changing demands with economic conditions, this model is appropriate when the retailer/manufacturer would have to adjust his or her inventory policy and production schedule according to the current price elasticity of demand dictated by the market.

Although this model is limited by the fact that it assumes deterministic customer behavior (or deterministic price elasticity) and any lack of competitive reactions to one's action, it does provide the ground work to take on a new direction of inventory management in supply chain. In addition, it provides a way to reset initial pricing to optimize profit, and the marginal rate of price increase during an inventory cycle. The most beneficial of it all is that the solutions are only dependent on the assumed price elasticity and cost data, and can be revised easily should the market conditions change again.

In what follows, we first recapitulate Whitin's (1955) and Kunreuther and Richard's (1971) fixed price strategy model with gradual usage cycle as described in Chase et al (2010). In the next section, we present our own model. The derived model has a polynomial objective function, and hence, does not have a closed form solution. However, we are still able to provide the optimal initial pricing and the marginal rate of price increase during the cycle easily. Using Microsoft Solver®, we utilize several numerical examples with a linear demand curve and varied values of relevant parameters. The final section provides the conclusions of our analysis along with some directions for future research.

THE FIXED PRICE GRADUAL USAGE MODEL

Both papers of Whitin (1955), Kunreuther and Richard (1971) consider a situation where all the other assumptions of the EOQ model are valid but demand is price sensitive, with a known and stationary demand curve. Whitin's (1955) notation is different from Kunreuther and Richard's (1971) notation. There are also some minor differences in the details of the two models. In addition with Chase et al (2010) for gradual usage assumption, the following captures the basics of these models. Although the model is applicable to any form of the demand function, for simplicity, we use a linear demand function.

Let the following notations hold,

C = retailer's known and constant unit cost of buying the product,
S = retailer's known and constant ordering cost per order,
I = retailer's carrying costs per dollar of inventory per year,
P_1 = retailer's selling price per unit in this model,
m = constant production rate per period,
t = time elapsed from the beginning of an inventory cycle,
Y_1 = retailer's profit per cycle,
Z_1 = retailer's profit per period

It is assumed that,

$P_1 > C,$ and D_1 = retailer's annual demand as a function of the selling price, P_1, hence, $D_1 = a - b\ P_1$where a and b are nonnegative constants, a representing the theoretical maximum annual demand (at the hypothetical price of \$0 per unit) and b representing the demand elasticity (i.e., the reduction in annual demand per dollar increase in price). Although P1 would remain constant throughout a cycle, we choose to express it in an affine function form to be consistent with the price increasing model in the next section.

Note that since D_1 must be positive for the conceivable range of values of P_1, $a > bP_1$ for that range of values of P_1, and since $P_1 > C$, it follows that $a > bC$.

Let

T_1 = the duration of retailer's gradual replenishment in an inventory cycle, and
T_2 = the duration of retailer's inventory cycle (replenishment and consumption).

Note that $T_2 > T_1$. Further, let

Q = retailer's order quantity per order in this model. Then, $Q = D_1T_2 = (a\text{-}bP_1)T_2$. The maximum inventory level would then be $mT_1\text{-}DT_1 = (m\text{-}a\text{+}bP_1)T_1$.

From $T_1 \geq t \geq T_2$, the retailer would be consuming from the inventory at a rate of D_1t until the end of the cycle, T_2. That is, we have

$(m\text{-}a+bP_1)T_1 = D_1(T_2\text{-}T_1)$, or
$$T_1 = [(a\text{-}bP_1)/m]T_2 \quad (1)$$

The retailer's profit per cycle, Y is given by

$$Y_1 = (P_1\text{-}C)D_1T_2\text{-}IC[T_1(m\text{-}a+bP_1)/2]T_1\text{-}IC[T_1(m\text{-}a+bP_1)/2](T_2\text{-}T_1)\text{-S} \quad (2)$$

Thus, the retailer's profit per period, Z_1 is obtained by Y_1/T_2, and by substituting (1) into Y_1, we have,

$$Z_1 = (P_1\text{-}C)(a\text{-}bP_1)\text{-}IC[(m/2)\text{-}(a\text{-}bP_1)/2][(a\text{-}bP_1)/m]T_2\text{-}(S/T_2) \quad (3)$$

Differentiating Z_1 with respect to P_1 and T_2, the first-order conditions for the maximization of this function are:

$$P_1 = [(a/b)+C+(ICT_2/2)\text{-}(aICT_2/m)]/[2\text{-}(bICT_2/m)] \quad (4)$$

$$T_2^2 = 2S/\{(IC)(a\text{-}bP_1)[1\text{-}(a\text{-}bP_1)/m]\} \quad (5)$$

Notice that Equation (5) is equivalent of the gradual usage (or production) model as illustrated in Chase et al (2010) .

Combining Equations (4) and (5) and simplifying, we have an explicit quartic equation in terms of T_2:

$$I^3C^3b^3T_2^4\text{-}4mI^2C^2bT_2^3+IC[8am\text{-}8mbC\text{-}4a^2+8abC\text{-}4b^2C^2\text{-}4SICb^2]T_2^2$$
$$+16SmICbT_2\text{-}16Sm^2 = 0 \quad (6)$$

As we can see here, we can solve Equation (6) for T_2 which has 4 roots. To obtain these roots, one may use MathCAD to find all the closed form solutions in terms of the coefficients of T_2, and substituting them into (3) to see which root would optimize Z_1. On the other hand, one may use other software to solve (4) and (5) simultaneously. However, we elect to use Excel Solver® to solve for P_1 and T_2 simultaneously for optimal Z_1. To ensure solution quality, we have also implemented the constraints such as $P_1 > C$, and so on. We then verify the solution with (4), (5) and (6). Once care is taken to input these conditions and reasonable starting values, in our experimentation, Excel Solver has never failed to return the best real solution (if any). Hence, we believe that practicing managers would be adequately served by the use of Excel Solver. They need not worry about obtaining all the roots of the quartic equation.

THE CONTINUOUSLY INCREASING PRICE GRADUAL USAGE MODEL

We retain all of the assumptions of the foregoing model, except that now we assume that the retailer uses a continuously increasing price strategy within each inventory cycle.

Let us add the following notation:

$P_2(t)$ = the retailer's selling price at time t, and $P_2(t) = f+gt$, where f and g are nonnegative decision variables, and $f > C$. f represents the retail price at the beginning of each inventory cycle and g represents the annual rate of increase in the retail price throughout an inventory cycle.
Y_2 = retailer's profit per cycle, and
Z_2 = retailer's profit per period.
$X(t)$ = the retailer's inventory level at time t, with $X(0) = 0$, $X(T_2) = 0$, and
$X(T_1)$ = the maximum inventory level in an inventory cycle.
$D_2(t) = a-bP_2(t)$ = retailer's demand as a function of the selling price.

Given that price is a function of time, now the retailer's annual demand rate will also be a function of time. Hence, we should redefine demand as

$$D_2(t) = a-bP_2(t) = a-bf-bgt \tag{7}$$

Since at the beginning of the inventory cycle, the retailer orders a quantity Q to meet the cycle time demand, and with the gradual production rate, m,

$Q = mT_1$
$X(t)$, the inventory level at time t, for $0 < t < T_1$, is
$X(t) = \int_0^t [m - D(t)]\mathrm{d}t = mt-at+bft+\frac{1}{2}bgt^2$

At T_1, the maximum inventory level is reached, and

$$X(T_1) = mT_1-aT_1+bfT_1+\frac{1}{2}bgT_1^2 \tag{8}$$

At the end of an inventory cycle, $X(T_2) = 0$. That is,

$X(T_2) = mT_1-aT_2+bfT_2+\frac{1}{2}bgT_2^2 = 0$ which implies

$$T_1 = (aT_2-bfT_2-\frac{1}{2}bgT_2^2)/m \tag{9}$$

The retailer's profit per inventory cycle is given by,

$$Y_2 = \int_0^{T2}[P(t) - C]D(t)\mathrm{d}t - IC\int_0^{T1} X(t)\mathrm{d}t - IC\int_{T1}^{T2} X(t)\mathrm{d}t - S \quad (10)$$

Substituting (9) after evaluating (10), we obtain,

$$Y_2 = (af-aC-bf^2+bCf)T_2+\tfrac{1}{2}(ag-2bfg+bCg)T_2^2-\tfrac{1}{3}bg^2T_2^3$$
$$-IC\{\tfrac{1}{2}(T_2^2/m)[a^2-2abf+b^2f^2-abgT_2+b^2fgT_2+\tfrac{1}{4}b^2g^2T_2^2]+T_2^2(\tfrac{1}{2}a-\tfrac{1}{2}bf-\tfrac{1}{3}bgT_2)\}-S \quad (11)$$

The profit per period, $Z_2 = Y_2/T_2$ is,

$$Z_2 = (af-aC-bf^2+bCf) +\tfrac{1}{2}(ag-2bfg+bcg)T_2-\tfrac{1}{3}bg^2T_2^2$$
$$-IC\{\tfrac{1}{2}(T_2/m)[a^2-2abf+b^2f^2-abgT_2+b^2fgT_2+\tfrac{1}{4}b^2g^2T_2^2]+T_2(\tfrac{1}{2}a-\tfrac{1}{2}bf-\tfrac{1}{3}bgT_2)\}-S/T_2 \quad (12)$$

Differentiating Z_2 with respect to T_2, f, and g, for the first order optimal conditions by setting them to zero, we have, respectively,

$$\partial Z_2/\partial T_2 = \tfrac{1}{2}(ag-2bfg+bCg)-\tfrac{2}{3}bg^2T_2$$
$$-IC\{(1/2m)[a^2-2abf+b^2f)-2abgT_2+2b^2fgT_2+\tfrac{3}{4}b^2g^2T_2^2]+(\tfrac{1}{2}a-\tfrac{1}{2}bf-\tfrac{2}{3}bgT_2)\}+S/T_2^2 = 0 \quad (13)$$

$$\partial Z_2/\partial f = (a-2bf+bC)-bgT_2-IC\{T_2/2m[-2ab+2bf+b^2gT_2]-\tfrac{1}{2}bT_2\} = 0 \quad (14)$$

$$\partial Z_2/\partial g = \tfrac{1}{2}(a-2bf+bC)T_2-\tfrac{2}{3}bgT_2^2-IC\{T_2/2m[-abT_2+b^2fT_2+\tfrac{1}{2}b^2gT_2^2]-\tfrac{1}{3}bT_2^2\} = 0, \text{ or}$$
$$\tfrac{1}{2}(a-2bf+bC) -\tfrac{2}{3}bgT_2-IC\{\tfrac{1}{2}m[-abT_2+b^2fT_2+\tfrac{1}{2}b^2gT_2^2]-\tfrac{1}{3}bT_2\} = 0, \text{ if } T_2 > 0 \quad (15)$$

From (14) and (15), we obtain,

$$f = [a+bC+\tfrac{1}{m}(ICabT_2)-\tfrac{1}{4m}(ICbT_2)^2]$$
$$/[2b+\tfrac{3}{m}(ICbT_2)(1-b)+\tfrac{1}{m}(ICbT_2)+(3/2m^2)(ICbT_2)^2(1-b)] \quad (16)$$

and,

$$g = (3/m)ICf(1-b)+\tfrac{1}{2}IC(17) \quad (17)$$

Notice that f represents the initial price set at the beginning of the inventory cycle, and the marginal increase during the cycle is given by g as in Equation (17). Also note that when m approaches infinity as in the case of basic EOQ models with instantaneous replenishment, g would be equal to IC, same as the basic model.

Of course, when we replace f and g in Equation (13), we would obtain an explicit polynomial function of T_2, that is, of fifth order, or quintic function. There is, unfortunately, no close form solution for any polynomial function higher than quartic. For practitioners, we would, once again, rely on Excel Solver which has demonstrated to be a reliable tool for obtaining an optimal solution.

NUMERICAL EXAMPLE: BASE CASE

Consider a situation where the retailer's cost of a product is \$5 per unit. The theoretical maximum periodic demand is 20 units and periodic demand declines at the rate of 1 unit for each dollar's increase in the price. The ordering costs are \$100 per order and the carrying costs are \$0.05 per dollar of inventory per period. The production rate is 40 units per period. We will refer to this set of assumptions as the base case.

Table 1: A numerical example.

Assumptions common to both models C = \$5/unit; a = 20 units/period; b = 1 unit/period; S = \$100/order; I = \$0.05/\$/period; m = 40 units/period				
Optimal Decisions and Consequences Under the Two Models				
		Fixed Price Model	Continuously Increasing Price Model	Percent Difference Between the Models
Optimal Decisions	Production periods, T_1	1.1272	1.7387	54%
	Cycle time, T_2	10.35047204	12.11802081	17.08%
	Price at beginnig of cycle, f	\$15.64/unit	\$12.75	-18.48%
	Price increase rate per period, g	None	\$0.125/unit	NA
Consequences	Order quantity, Q	45.088/order	69.548/order	54.25%
	Price at the end of the cycle (= $f + gt$)	\$15.64/unit	\$14.26/unit	-8.80%
	Profit per period, Z	\$31.08	\$39.88	28.31%

Table 1 summarizes the base case assumptions, the optimal decisions and the consequences under the two models. As can be seen there, in the fixed price model, the optimal retail price is \$15.64 per unit and the optimal inventory cycle time is 10.35 periods. This means that the retailer would order 45.088 units per order and would obtain per period profit of \$31.08.

In the continuously increasing price production model, the starting retail price is \$12.75 per unit at the beginning of the cycle and that price increases at the rate of \$0.125 per period. The optimal cycle time is 12.118 periods. This means that the retail price at the end of the cycle is

$14.26 per unit, the retailer would order 69.548 units per order and would achieve a periodic profit of $39.88.

In addition to reporting these numbers, Table 1 also presents the percent differences between the two models for each relevant decision and consequence. Observe that, in percent terms, the differences are rather substantial. In comparison with the fixed price strategy, the continuously increasing price strategy results in a longer cycle time of 17.08 percent. At the beginning of an inventory cycle, under the continuously increasing price model, the retail price is smaller than what it is under the fixed price model. However, by the end of the cycle, the retail price under the continuously increasing price model is still lower than what it is under the fixed price model. As a result, the periodic demand is larger under the continuously increasing price model. The average cycle profit shows a substantial improvement of 28.31 percent in the continuously increasing price model compared to the per cycle profit under the fixed price model. This shows that continuously pricing model performs substantially better than a fixed pricing model by taking advantage of the gradual usage/replenishment, and the pricing elasticity.

The specific numerical results we have obtained are a function of the numerical assumptions we have made. Hence, in order to identify the circumstances under which the continuously increasing price strategy would be particularly desirable, we carried out a sensitivity analysis, as described in the following section.

SENSITIVITY ANALYSIS

Table 2 summarizes the results of an analysis where we increased the value of each one of our parameters (except the last row which indicates a decrease in production level), one at a time, while maintaining the values of the other parameters constant. In each case, Table 2 shows the consequences of these changes on the retailer's annual profits under the two models and the percentage increase in the periodic profit that the retailer obtains by using the continuously increasing price gradual usage strategy as against using the fixed price strategy. For comparison purposes, the first row of Table 2 repeats the profit results of the two models in the base case.

Table 2. Sensitivity Analysis

	A comparison of the periodic profit under the two models		
Changed assumption(s)	Fixed price gradual usage model	Continuously increasing price gradual usage model	Percent Difference Between the Two Models
None (Base Case)	$31.08/period	$39.88/period	28.31%
S = $150/order	$33.22/period	$36.16/period	8.85%
b = 1.2 units/period	$22.71/period	$26.17/period	15.24%
I = 0.1/unit/period	$29.78/period	$33.01/period	10.85%
m = 80	$37.32/period	$37.95/period	1.69%
m = 20	$37.40/period	$46.36/period	23.96%

While other things remain constant, any increase in ordering cost, elasticity, inventory holding rate, and production/replenishment rate would still favor the continuously increasing price strategy. With the exception of production/replenishment rate, the periodic profits can increase rather significantly over those of the fixed price model, although the differences are getting narrower. In particular, when the production/replenishment rate is doubled, the profit difference is only 1.69%. This, we believe is due to the fact the demand rate, *m*, is due to the fact that when increasing production/replenishment rate would be equivalent to switching gradual production to instantaneous delivery of the basic EOQ model. As Joglekar et al (2008) has pointed out that the percentage changes would be small under the basic EOQ assumptions.

The additional analysis of decreasing the production/replenishment rate, *m*, is shown in the last row of Table 2. Notice that the gradual usage model discussed in Chase et al (2010) exhibits lower inventory cost if *m* approaches the periodic demand. In the continuously increasing price strategy, the profit increase is even more pronounced given the fact that we would now take advantage of the slower replenishment, as well as the price elasticity leading to a 23.96% increase with $m = 20$ over the fixed price model.

Of course, our sensitivity analysis focused on changes in one parameter at a time. When several parameters are favorable to the continuously increasing price strategy, the gains offered by this strategy may be even more significant.

CONCLUSIONS

Traditionally, operations researchers (Whitin, 1955: Kunreuther & Richard, 1971, and others) have assumed that when a product's demand curve is known and stationary, a retailer of the product would find it optimal to buy a fixed quantity every time he buys and to sell the product at a fixed price throughout the year. Joglekar et al (2008) found that the continuously increasing price strategy would increase the periodic profit abide the small gains. With the gradual usage assumption, Chase et al (2010) shows that by take advantage of the non-instantaneous production/replenishment rate, the total inventory cost could be reduced. However, when employing the continuously increasing price strategy in this situation as proposed by Joglekar et al (2008), we find that the profit per period would increase significantly as indicated in the numerical examples in the previous sections.

A continuously increasing price strategy might be impractical in the past, but with the new technology today, e-tailers can easily update their prices continuously. Elmaghraby and Keskinocak's (2003) review of dynamic price models indicates that a number of industries are already using continuously changing pricing strategies.

With the recent economic downturn, retailers are more conscientious of their inventory and pricing. The ever changing retail environment may warrant a new and more dynamic strategy in order to remain competitive in the market place. Our model provides a practical and systematic approach to coordinate a supply chain's sales and productions. In addition, it provides an easy computational tool of the initial price and the marginal rate of increase. Should the business environments change; a new pricing scheme can be quickly re-configured and implemented just like what we have shown with our formulas in section 3.

Our numerical example suggests that the advantage of a continuously increasing price strategy is significant and the sensitivity analysis shows that this strategy is particularly desirable when demand is highly price sensitive or when an e-tailer's supplier commands great pricing power. While the continuously increasing price strategy may not be practical for a brick-and-mortar retailer, such a retailer could use the dual price strategy model developed by Joglekar (2003) that a retailer who sets two different prices at two different points in an inventory cycle obtains a greater profit than a retailer using a single fixed price throughout the cycle. Although Joglekar et al (2008) model only shows modest gains under the basic EOQ assumptions, the continuously increasing price strategy with gradual usage (or non-instantaneous replenishment) provides significantly higher profits. In addition, it provides an avenue where retailers can adjust their pricing schemes in a hurry when the market conditions call for sudden and significant changes in price elasticity.

There are several directions in which this research can be further investigated. In this paper, we have extended the Joglekar et al (2008) model for a retailer who is also a manufacturer of the product. Some retailers have now adopted the pre-ordering strategy (such as game console, smart phones, and so on), which is similar to back-ordering. This extension would do well for those with different pre-order and initial prices to maximize profit. Finally, a number of recent models coordinating pricing and order quantity decisions across a supply chain [23-26] have assumed a fixed price for each participant of the supply chain. These models also need to be updated by considering a continuously increasing price strategy.

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REFERENCES

Abad, P. L.(1997) Optimal policy for a reseller when the supplier offers a temporary reduction in price, *Decision Sciences*, 28(3), 637–649

Abad, P. L. (2003). Optimal price and lot size when the supplier offers a temporary price reduction over an interval, *Computers and Operations Research*, 30(1), 63–74.

Arcelus, F. J. & G. Srinivasan (1987), Inventory policies under various optimizing criteria and variable markup rates, *Management Science*, 33(6), 756–762

Arcelus, F. J. & G. Srinivasan, (1998). Ordering policies under one time only discount and price sensitive demand, *IIE Transactions*, 30(11), 1057–1064.

Ardalan, A. (1991) Combined optimal price and optimal inventory replenishment policies when a sale results in increase in demand, *Computers and Operations Research*, 18(8), 721–730.

Boyaci, T. & G. Gallego, (2002). Coordinating pricing and inventory replenishment policies for one wholesaler and one or more geographically dispersed retailers, *International Journal of Production Economics*, 77(2), 95–111

Chase, R. B., F. R. Jacobs & N. J. Aquilano, (2010). *Operations management with competitive advantage,* McGraw-Hill/Irwin, 13th Edition

Elmaghraby W. & P. Keskinocak, (2003). Dynamic pricing in the presence of inventory considerations: research overview, current practices, and future directions, *Management Science*, 49(10),. 1287–1309.

Feng, Y. & B. Xiao, (2000). Continuous-time yield management model with multiple prices and reversible price changes, *Management Science*, 46(5), 644–657

Hall, R.(1992) Price changes and order quantities: impacts of discount rate and storage costs, *IIE Transactions*, 24(2), 104–110.

Harris, F. (1913) How many parts to make at once, *Factory, The Magazine of Management*, 10(2),.

Joglekar, P. , (2003). Optimal price and order quantity strategies for the reseller of a product with price sensitive demand, Proceedings of the Academy of Information and Management Sciences, 7(1), 13–19

Joglekar, P., P. Lee & A. M. Farahani, (2008). Continuously increasing price in an inventory cycle: An optimal strategy for e-tailers, *Journal of Applied Mathematics and Decision Sciences,* 2008(483267),.

Kunreuther, H. &J. F. Richard, (1971). Optimal pricing and inventory decisions for non-seasonal items, *Econometrica*, 39(1), 173–175

Martin, G. E. (1994). Note on an EOQ model with a temporary sale price, *International Journal of Production Economics*, 37(2-3), 241–243.

McGill, J. I. &G. J. van Ryzin, (1999). Revenue management: research overview and prospects, *Transportation Science*, 33(2), 233–256

Rajan, A, R. Steinberg & R. Steinberg, (2002). Dynamic pricing and ordering decisions by a monopolist, *Management Science*, 38(2), 240–262.

Smith, B. C., J. F. Leimkuhler & R. M. Darrow, (1992). Yield management at American Airlines, *Interfaces*, 27(1), 8–31

Talluri, K. T. & J. G. van Ryzin,(2000). *The Theory and Practice of Revenue Management*, Kluwer Academic Publishers, Dordrecht, The Netherlands

Tersine, R. J. & R. L. Price, (1981). Temporary price discounts and EOQ, *Journal of Purchasing and Materials Management*, 17(4), 23–27

Weatherford, L. R. & S. E. Bodily, (1992). A taxonomy and research overview of perishable-asset revenue management: yield management, overbooking and pricing, *Operations Research*, 40(5), 831–844.

Weng, Z. K.& R. T. Wong, (1993). General models for the supplier's all unit quantity discount policy, *Naval Research Logistics*, 40(7), 971–991.

Weng, Z. K. (1995). , Channel coordination and quantity discounts," *Management Science*, 41(9), 1509–1522.

Wend, Z. K. (1995). Modeling quantity discounts under general price-sensitive demand functions: optimal policies and relationships, *European Journal of Operational Research*, 86(2), 300–314.

Whitin, T. M. (1955). Inventory control and price theory, *Management Science*, 2(1),. 61–68

Wilson, R.(1934). Scientific routine for stock control, *Harvard Business Review*, 13(1).

MODELING TRAFFIC ACCIDENTS AT SIGNALIZED INTERSECTIONS IN THE CITY OF NORFOLK, VA

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ABSTRACT

This study was an attempt to apply a proactive approach using traffic pattern and signalized intersection characteristics to predict accident rates at signalized intersections in a city's arterial network. An earlier analysis of accident data at selected intersections within the City of Norfolk indicated that in addition to traffic volume, other controllable factors contributed to traffic accidents at specific intersections. These factors included area topography, lane patterns, type of road signs, turning lanes, etc. It is also known that administrative factors such as signal types, signal polices, road closures, etc., and maintenance factors such as road conditions, condition of the signals, condition of road signs, etc. also impact road accidents.

The objective of this study was to relate these variables to accident rate and delineate variables that are statistically more significant for accident rate. Data on several topographical variables was collected in the City of Norfolk. These variables included number of lanes, turn lanes, pedestrian crossing, restricted lanes, etc. A linear regression model was used to establish relationship between these variables and the accident rate. The resulting regression model explained 60% of the variability. It also showed that four topographical variables are more important than other variables. These variables include number of lanes, number of turn lanes, presence of median and presence of permanent hazard like railway crossing. However, validation of model showed higher than expected variation. The model developed, in this study, overestimates the accident rate by 33%, thus, limiting its practical application.

INTRODUCTION

The main objective of this research was to study the signalized intersection in a city to delineate intersection geometry and design factors which may be contributing to traffic accidents. The City of Norfolk was selected for this study since it is one of the largest and oldest cities in the Hampton Roads region; and is home to roughly quarter million people. In 2006 the Hampton Roads had the highest crash incidents in the state based on the millions of VMT (vehicle mile traveled) (Nichols, 2007). The City of Norfolk contributed roughly 17% of those crashes with annual traffic accident count of approximately 5,400.

The literature review shows that road design factors could impact traffic safety. Several highway engineering factors like lane widths, shoulder widths, horizontal curvature, vertical curvature, super-elevation rate, median, auxiliary lane, etc. are estimated based on some traffic safety considerations. Additional factors like road signage, vegetation, line sight of signal especially on horizontal and vertical curvature, and number of driveways have also been reported to have impact on the traffic safety. To study the impact of these factors along with traffic control rules, researchers have utilized variety of statistical models. The most often used model is multivariate regression where the dependent variable is generally based on traffic accidents and a set of independent variables including roadway design, traffic control, demographic variables, etc. The negative binomial model is used to account for large variability among the accident rates on different intersections. Research results show relationship exists between the various roadway design and control factors and traffic accidents. Research also indicates divergences on the importance of individual factor on the traffic safety. There is reported difference based on the regional demographic factors indicating regional accident rate differences due to interactions between design/control factors and local driving population. This study was designed to understand the impact of the road design factors on the traffic accident rate in a local area.

This study was preceded by a pilot study conducted in the City of Norfolk for signalized intersections (Maheshwari and D'Souza, 2008). An intersection accident was defined as any accident occurring within the 250' of the intersection. The pilot study results showed that intersection topography/design factors and traffic control rules have positive relationship with the traffic accident rate. These factors included number of driveways, pedestrian crossing, and presence of physical median. Despite indicating number of positive relationships, the pilot study results could not be generalized as the sample size was very small. A sample of ten intersections was selected based solely on the accident rate. Also, the pilot study model was not validated for other intersections in the City. Hence, it was logical to further investigate the impact of topographical and other controllable factors on the traffic accidents with an expanded sample size and validate the model using other intersections within the City.

LITERATURE REVIEW

Automobile accidents contribute to staggering amount of property damage and large number of deaths in United States. According to the Insurance Information Institute, New York (Hot Topic and Issues Update: Auto Crashes, 2006), 42,636 people died in motor vehicle crashes in 2004 alone and an additional 2,788,000 people were injured. There were over 6 million police reported auto accidents in 2004. It is reported that about 50% of crashes occur at the intersections (Hakkert & Mahalel, 1978; National Highway R&T Partnership, 2002). It has been reported extensively in the literature that traffic volume is the major explanatory factor for traffic accidents (Vogt, 1999). However, studies have been carried out showing that design and other related factors contribute towards 2% - 14% of accidents. Ogden, et al., 1994 reported that about 21% of the variation in accidents was explained by variations in traffic flow volume, while the remaining majority of the variation was explained by other related factors. Vogt (1999) provides an extensive review of the factors, which have been considered in past research studies. These factors include channelization (right and left turn lane), sight distance, intersection angle, median width, surface width, shoulder width, signal characteristics, lighting, roadside condition, truck percentage in the traffic volume, posted speed, weather, etc. Beside these factors, researchers have also considered other minor details such as surface bumps, potholes, pavement roughness, pavement edge drop-off, etc. (Graves, et al., 2005).

The relationship between the accidents and pertinent factors is usually established using multivariate analysis (Corben & Foong, 1990; Hakkert & Mahalel, 1978; Ogden, et al., 1994; Ogden and Newstead, 1994; Vogt, 1999). A study by Corben and Foong, 1990 led to development of a seven-variable linear regression model for predicting right-turn crashes at signalized intersections. This model explained 85% of the variance of accident occurrence. In a FHWA study by Harwood, et al., (2000), quantitative data on accidents and other factors were combined with the expert's judgment about design factors as well as expected impact of these design factors on the accident rate. Mountain, Fawaz & Jarrett (1996) showed in a British study that the road design features- link length relates to accident rate, especially in dual carriageway. Retting, et at. (2001) studied the affect of roundabout on the traffic accidents; and found that replacing signals or stop signs with roundabouts could reduce traffic accidents. Road design factors like, the curve radii, spiral lengths, lane width, shoulder width, and tangent lengths are shown to be related the collusion frequency (Easa and Mehmood, 2008). It was exhibited through a comprehensive study of Korean road accident data that three categories of factors influence the accident rate -- road geometric condition, driver characteristic and vehicle type (Lee, Chung & Son, 2008). Wang, Quddus and Ison (2009) studied roadways based on congestion and reported that beside traffic volume, segment length, number or lanes, curvature and gradient also influence the accident rates.

Malyshkina and Mannering (2010) studied the impact of design exceptions allowed in the highway construction on the traffic accident rate (design exception: safety deviation in roadway design factors). They found exceptions don't necessarily increase accidents in their dataset. In another analysis of the data of 10 Canadian cities, Andrey (2010) related weather and accident rates and found that accident rates drop under severe weather conditions.

It is clear from the research that variety of statistical models are used for traffic accident analsysis, however, it is evident from the literature that negative binominal or Poisson distribution is often employed in relating the frequency of accidents to design factors (Lord, Guikema, Geedipally, 2008; Malyshkina and Mannering ,2010; Shankar, Manning and Barfield 1995; and Wang and Abdel-Aty, 2008). The technique is largely used to account for the higher variability in the frequency of accidents at different intersection. For example, Shankar, et al. (1995) used negative binomial distribution to show interaction between roadway geometry factors and weather accidents. They showed that certain geometry elements are more critical during the severe weather conditions. Milton, Shankar, & Mannering (2008) used logit model to include several parameters like weather, type of traffic, and road geometry.

Recent studies have applied data mining techniques along with statistical modeling to determine the impact of major factors like traffic volume and road design characteristics along with minor factors such as potholes and surface roughness. Graves, et al., (2005) reported about the impact of potholes and surface roughness on the accident rate. However, due to the paucity of data, a clear link could not be established between these surface factors (pot holes, roughness, etc.). Washington, et al., (2005) performed an extensive study to validate previously reported accident prediction models and methods. Validation was performed using recalculation of original model coefficients using additional year's data as well as using data from a different state. The study reported that beside traffic volume other factors should be considered on a case-by-case basis for a given site.

The literature discusses the variety of factors affecting traffic accidents including road geometry, layout and traffic control factors. However, there is divergence of opinion on what factors have more influence on safety. Also, there are regional differences in the importance of factors which influence safety. Studies on rural highways are not directly applicable to urban settings as the traffic pattern and other factors differ at rural and city intersections. Furthermore, before and after studies may be less valuable in rural settings as road design changes are not made as often as in a city with growing traffic volume. Moreover, literature shows that traffic accident analyses are commonly conducted in a larger geographical area (one or more states). This research was build upon past research and evidence from the literature to apply a systematic approach of identifying factors in accident-prone intersections in a city such as Norfolk, VA and analyzing factors which could significantly influence the accident rates in that specific area.

METHODOLOGY

The approach in this research was to collect and analyze data from the intersections with higher accident rates in the City. Restricting data set to higher accident intersections allows to reduce the variability in the data set. Therefore, it makes generalized linear model (GLM) applicable for the analysis of the data set. The study was conducted for the signalized intersections within the City of Norfolk, VA. The study concentrated on 65 signalized intersections that experienced high accident rates during the period 2001-2004. Thirty of these intersections were selected for the analysis and 10 were used for validation. Rest of the intersections could not be used because of traffic count data for those intersections were not available.

The City of Norfolk has stored traffic accident data in an electronic format for the past 11 years from 1994 to 2004. Only accidents related to single vehicles were considered in the study due to technical limitations of importing multi-vehicle into the available database. The City's accident database was developed from individual police accident reports that included type of accident, road conditions, traffic signs and signal, drivers' actions, vehicle(s) condition, demographic data, nature of injury, and other related information, all of which are subsequently entered in the City's accident database. The traffic accidents without a police report were not included in this database hence those accident were not part of this study. The traffic volume data, Annual Average Daily Traffic (AADT), was obtained from the Department of Transportation, Commonwealth of Virginia. Some of the local and feeder roads traffic count were not available hence those intersections were eliminated from the study.

The physical attributes included number of lanes, type of lanes, type of turn signals, existence of median and shoulder, pedestrian crossing, number of driveways within 250' of the intersection, and other safety features. A schematic of the intersection is shown in Figure 1. For each intersection, 56 different physical attributes were collected. The AADT data was collected from the Department of Transportation, Commonwealth of Virginia. A review of data revealed that the certain variables could be eliminated as they were rarely present in the data collected, this included shoulder variables and no right turn signal. This reduced the variable set to 44 independent variables.

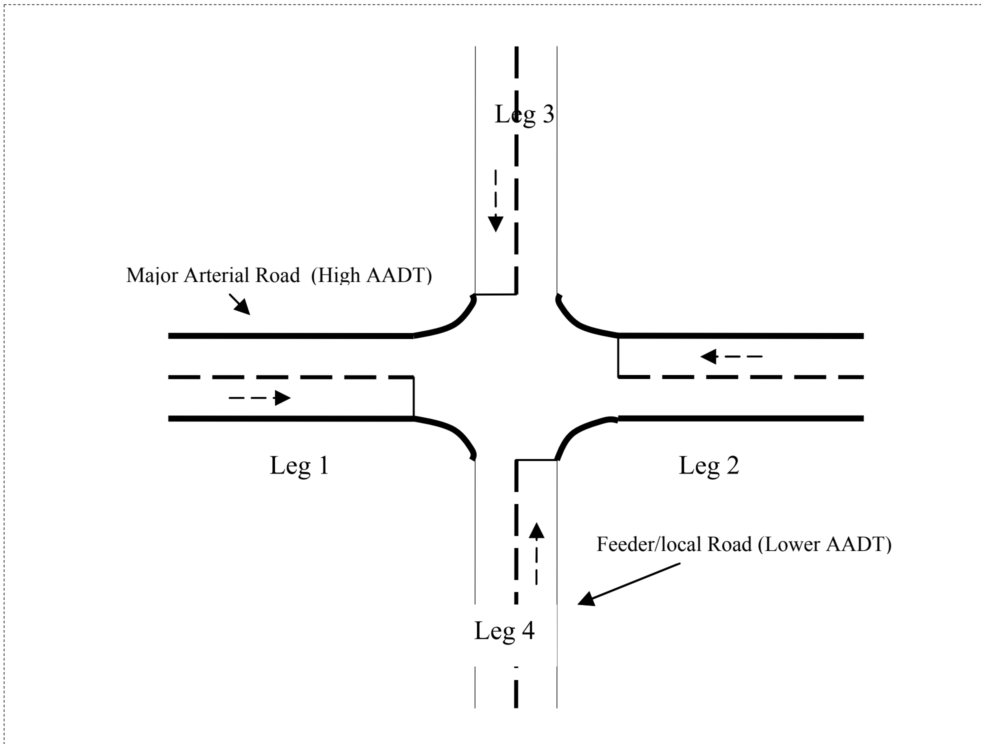
The traffic volume for the 40 intersections was computed using the Annual Average Daily Traffic (AADT) data published by the Commonwealth of Virginia. The total AADT for each intersection was calculated by adding traffic (AADT) coming into and leaving the intersection for both highways. The total AADT at an intersection is the sum of the average of AADT for the each highway as follows:

> Intersection total AADT = {[(Traffic Volume Approaching the Intersection from Direction 1 + Traffic Volume Leaving Intersection from Direction 1)/2]+[(Traffic Volume Approaching the Intersection from Direction 2 + Traffic Volume Leaving Intersection from Direction 2)/2]}

RESULT AND ANALYSIS

Although topographical data for each leg of the intersection was collected, accident data was not available for each leg. Therefore, a composite variable was created for the number of lanes, turn lanes etc. These composite variables were input into the regression model as the independent variables. A list of all independent variables is provided below in Table 1.

Figure 1. Schematic of an Intersection



The linear regression technique was used in this analysis in which total accident count was used as the dependent variable. Pearson correlation coefficients calculated are shown in Table 2.

Table 1. Independent Variables for the at Intersection Accident Model

Variable	Definition
AADT	Annual average daily traffic at the intersection
LANE	Total number of lanes at the intersection
TURN	Total number of turn lanes at the intersection
MEDN	Total number of physical median at the intersection (MEDN1+MEDN2+MEDN3+MEDN4)
PEDN	Total number of pedestrian crossing at the intersection (PEDN1+PEDN2+PEDN3+PEDN4)
DRWY	Total number of driveways at the intersection
HZRD	Number of legs with extra hazards at the intersection
EXSF	Number of legs with extra safety features at the intersection
RLFL	Number of legs with restricted left turn signal at the intersection.

The linear regression technique was used in this analysis in which total accident count was used as the dependent variable. Pearson correlation coefficients calculated are shown in Table 2.

Table 2. Correlation Coefficient

Variable	ACCT	p-Value	Sig at 10%
LANE	.502	0.00475261	Yes
TURN	.559	0.00133763	Yes
DRW	-.006	0.97315647	No
MEAD	.330	0.07532854	Yes
PEDN	-.083	0.66431599	No
EXSF	.024	0.89843575	No
HZRD	.578	0.00081547	Yes
RLTL	-.030	0.87507706	No
AADT	.416*	0.02214094	Yes

Above table shows that five variables: number of lanes, number of turn lanes, presence of medians, presence of hazards and AADT, are significantly (at alpha of 10%) correlated to number of accidents. A linear regression model was developed using these variables. Coefficients of the model are presented below in the Table 3.

The linear model analysis showed that regression accounted for 60% of variability in the accident rate (R-square = .602). The analysis of variance of the regression model shows that the variability explained by the model was significant at less than 1% level.

Table 3. Linear Model Coefficient

Constant	7.246
LANE	.438
TURN	3.225
MEAD	.596
HZRD	13.751
AADT	.001

The regression model can be written as:

$$ACCTOL = 7.246 + 0.438*LANE + 3.225*TURN + 0.596*MEAD + 0.001*AADT + 13.751*HZRD$$

Where ACCTOL—Total number of accidents at different intersections.

This result was significantly different than the pilot study result where R-square was 97%. The pilot study indicated that factors like number of driveways and pedestrian crossing were significant whereas presence of extra hazard (railway line, another traffic light with 250', etc.) factors were not significant.

To validate results, the current model was used to predict the total number of accidents in a different set of ten intersections. It was found that the model was predicting higher than the actual number of accidents. This difference between actual and predicted values was on an **average** more than 33% higher. A t-test was conducted and difference between actual and predicted values was found to be significant with p-value of .003. Table 4 shows the results.

Table 4. Difference between Predicted and Actual Accidents

Street	Actual Accident	Predicted Accidents	Diff
1	46	49.07	3.07
2	49	54.69	5.69
3	42	63.67	21.67
4	17	29.74	12.74
5	35	53.16	18.16
6	37	54.98	17.98
7	21	43.40	22.40
8	12	24.78	12.78
9	36	36.33	0.33
10	38	32.12	-5.88
Total	333	441.95	108.95

DISCUSSION

This study was an attempt to replicate the result of the earlier pilot study. However, the model developed with a larger sample size could not confirm the results of the pilot study. The R-square dropped from 97% in the pilot study to 60%. This was a significant change in the explained variation of the accident rates.

Furthermore, the variables which were found to be significant at the pilot study were not the same in the current model. It was encouraging to see that the presence of pedestrian crossings and number of driveways was significant in the pilot study model, indicating that certain policy decisions can be made based on the results of that model. However, those variables are no longer significant in the current study. It could be due to the fact that pilot study sample size was more homogeneous both in terms of the number of accidents as well as in terms of traffic volume.

Stepwise regression technique was also used to eliminate the affect of multi-collinearity. The model resulting from the stepwise regression included only two variables in the model; those factors were presence of hazards and number of turn lanes. As expected it gave lower R-square than model using simple regression. The R-square from the stepwise regression model was just 52%.

CONCLUSIONS AND LIMITATIONS

This study attempted to replicate the earlier pilot study to relate the traffic accidents and controllable factors such as road design, signal policies, and other data prevalent at signalized intersections. However, it was not able to fully replicate the pilot study. A larger sample of 65 intersections was chosen out of which only 40 data points were usable. A regression model was developed but it could only explain 60% of variability in the accident rate. Based on this research and literature, it is clear that there is some relationship between the topographical, design, and other controllable factors (60% of variation explained), however, more factors must be included to improve the results. Nevertheless, the analysis shows that traffic accidents and certain factors like presence of hazards should be further evaluated to see if these factors could be included to mitigate accident rates in future.

This study has the following limitations:

i. The accident data set is 5 years old compared to data collection on the roadways.
ii. The current model was unable to account for 40% of accident variations.
iii. The model was tested in a different set of intersections and showed that it was over estimating the number of accident by approximately 33%. Hence, its predictive capabilities were limited.
iv. Study of the impact of controllable factors could be improved if data was collected over time to reflect the changes made in the roadways.
v. Data on other relevant factors such as signal policy, road closure, etc. were not available. These factors could have an impact on the accident rates.
vi. This study excluded low accident rate intersections that could result in a biased model and may not be applicable to lower accident rate intersections.
vii. Records of the current data on the intersection geometry were not available; hence, onsite observations were conducted. These observations could have been affected by observers' skill level, fatigue, distraction, etc.

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REFERENCES

Andrey, J. (2010). Long-Term Trends in Weather-Related Crash Risks. *Journal of Transport Geography.* 18 (2), 247-258.

Corben, B. F. and Foong Chee Wai (1990). Pro-Active Traffic Engineering Safety Study: Final Report Part 2 - Right-Turn-Against Crashes at Traffic Signals. *Monash University Accident Research Center Report*, Number 13, December, 1990, Victoria 3800, Australia.

Easa, S. M . and Mehmood, A. (2008). Optimizing Design of Highway Horizontal Alignments: New Substantive Safety Approach. *Computer-Aided Civil and Infrastructure Engineering*. 23 (7), 560-573.

Graves, S. J., Rochowiak, D. and Anderson, M. D. (2005). Mining and Analysis of Traffic Safety and Roadway Condition Data. University Transportation Center for Alabama , The University of Alabama, Tuscaloosa, AL. *UTCA Report* # 04310.

Hakkert, A.S. and Mahalel, D. (1978). Estimating the Number of Accidents at the Intersections Form a Knowledge of the Traffic Flows on the Approaches. *Accident Analysis and Prevention*. 10 (1), 69-79.

Harwood, D.W., Council, F.M., Hauer, E., Hughes, W.E., and Vogt A. (2000). Prediction of the Expected Safety Performance of Rural Two-Lane Highways Report. US Department of Transportation, Federal Highway Administration. *Report # FHWA-RD-99-207*.

Hot Topic and Issues Update: Auto Crashes (2006). Retrieved July 25, 2006 from http://www.iii.org/media/hottopics/insurance/test5./?table_sort_748377=6.

Lee, J., Chung, J. and Son, B. (2008). Analysis of Traffic Accident Size For Korean Highway Using Structural Equation Models. *Accident Analysis and Prevention*. 40(6), 1955-1963.

Lord, D., Guikema, S.D., Geedipally, S.R. (2008). Application of the Conway–Maxwell–Poisson generalized linear model for analyzing motor vehicle crashes. *Accident Analysis and Prevention.* 40 (3), 1123–1134.

Maheshwari, S. & D'Souza, K. (2008). Modeling Signalized Intersection Traffic Accidents: Empirical Study in City of Norfolk, VA. *International Academy of Business and Economics Journal of Business Research*, 8 (1) 219-238.

Malyshkina, N. &Mannering, F.(2010). Empirical Assessment of the Impact Of Highway Design Exceptions On The Frequency And Severity of Vehicle Accidents. *Accident Analysis and Prevention*. 42 (1), 131–139.

Milton, J.C., Shankar, V.N. and Mannering, F.L. (2008). Highway Accident Severities and the Mixed Logit Model: An Exploratory Empirical Analysis. *Accident Analysis and Prevention*. 40 (1), 260-266.

Mountain. L., Fawaz, B. and Jarrett D. (1996). Accident Prediction Models For Roads With Minor Junctions. *Accident Analysis and Prevention*. 28 6) 695-707.

National Highway R&T Partnership. (2002). Highway Research and Technology: the Need for Greater Investment. U. S. Department of Transportation, Washington, D.C.

Nichols, K.M. (2007). Hampton Roads Regional Safety Study: General Crash Data and Trend 2007 Update. http://www.hrpdc.org/Documents/Transportation/Gen_Crash_ Data _ Trends_07_Final.pdf

Ogden, K., Newstead, S., Ryan, P. &Gantzer, S. (1994). Factors Affecting Crashes at Signalized Intersections. *Monash University Accident Research Center Report,* Number 62, October, 1994, Victoria 3800, Australia.

Ogden, K. W. and Newstead, S. V. (1994). Analysis of Crash Patterns at Victorian Signalized Intersections. *Monash University Accident Research Center Report,* Number 60, February, 1994, ictoria 3800, Australia.

Retting, R.A., Persaud, B. N, Garden, P.E. and Lord, D. (2001). Crash and Injury Reduction Following Installation of Roundabouts in the United States. *American Journal of Public Health*. V 9, N4, 628-631.

Shankar, V., Mannering, F., and Barfield,W. (1995). Effect of Roadway Geometrics and Environmental Factors on Rural Freeway Accident Frequencies. *Accident Analysis and Prevention.* 27 (3), 371–389.

Vogt, A. (1999). Crash Models For Rural Intersections: Four-Lane by Two-Lane Stop-Controlled and Two-Lane by Two-Lane Signalized. *US Department of Transportation, Federal Highway Administration Report* #FHWA-RD-99-128.

Wang, X., Abdel-Aty, M. (2008). Modeling left-turn crash occurrence at signalized intersections by conflicting patterns. *Accident Analysis and Prevention.* 40 (1) 76–88.

Wang, C., Quddus, M.A. and Ison, S.G. (2009). Impact of Traffic Congestion on Road Accidents: A Spatial Analysis of the M25 Motorway in England. *Accident Analysis and Prevention*. 41(4), Pages 798-808.

Washington, S., Persaud, B,, Lyon, C. and Oh, J. (2005). Validation of Accident Models for Intersections. US Department of Transportation, *Federal Highway Administration Report* # FHWA-RD-03-*037*.

BUILDING A SECURE ENTERPRISE MODEL FOR CLOUD COMPUTING ENVIRONMENT

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ABSTRACT

Security is a major concern for enterprises and a good information security framework is essential for the continued success of enterprises that use cloud computing services with vendors. The ISO/IEC 27002 security standard is based on a management systems approach and is the choice of many enterprises for developing security programs. As enterprises are rapidly adopting cloud services for their businesses, measures need to be developed so that organizations can be assured of security in their businesses and can choose a suitable vendor for their computing needs. This research proposes a mechanism for managing security in a cloud computing environment using the ISO/IEC 27002 framework.

INTRODUCTION

Cloud computing is one of the most attractive technologies that has experienced rapid growth where vendors provide services to enterprises over the Internet. The promising future of cloud can be impeded by security concerns due to the complex nature of the cloud. This research will focus on developing secure measures in the cloud computing environment from an enterprise level perspective. Maturity levels are an effective way for managers in enterprises to measure the effectiveness of security for the organization. A number of security maturity models exist but a good choice is one that is aligned with business needs of an organization (Urquhart, 2010). The ISO/IEC 27002 framework does not have any mandatory requirements and the various categories in this framework will be analyzed for the cloud computing environment. The rest of this paper is organized as follows: Cloud computing is described in section 2 and the available security measures discussed in section 3. The ISO/IEC 27002 framework is explained in section 4. The application of the ISO/IEC 27002 framework to the cloud environment is described in section 5 followed by summary in the last section.

WHAT IS CLOUD COMPUTING?

In the cloud environment, computing resources are delivered as services to enterprises by vendors. Enterprises can access resources provided by the vendor using the Internet as opposed to hosting and operating them locally. From this simple definition of cloud, one can note that cloud computing offers many benefits. The cloud vendor does the maintenance of hardware and software, and the vendor can provide adequate resources and storage to enterprises if the demand increases. This scalability property is an advantage in cloud computing. Enterprises which use the services of the cloud vendor have an agreement with the vendor. Cloud vendors can offer software, platform, infrastructure, storage or combinations of these as services to enterprises. The enterprises do not have control over many issues in the cloud environment. Security is a major concern for these enterprises as many cloud vendors are not transparent on security matters. It is important that enterprises and the cloud vendors address security issues and have a negotiation referred to as service level agreements (SLA) (Creese, Hopkins, Pearson and Shen,2009). Enterprises need to make sure that SLA negotiations are maintained. In legal issues the enterprise has to take steps to find violations in the SLA (Chapin, Akridge, 2005).

In the cloud environment, the exact location of the data is hard to detect and the data may span across different countries and in case of legal issues are subject to laws of that nation. Cloud vendors may have multiple tenants and offer multi-tiered services. When enterprises use clouds, there is a high level of risk due to many enterprises or tenants sharing the cloud. The cloud vendor must ensure highest level of security to each of its clients. The cloud service provider may use different sub vendors for their services. A cloud vendor can provide infrastructure services but may use another vendor's service for software and hence the service is multi-tiered. With this of multi-tier service, the risk associated with each tier is high and with different vendors, implementing secure measures is complex. These issues must be addressed by the enterprises in service level agreement with vendors.

An enterprise may be locked in with cloud vendor and transfer of data or change of vendor may not be easy to accomplish. There are many issues to be addressed by enterprises in using services of vendors as: transfer of data if vendor goes out of business, change of applications or platforms in using vendors, integration of security policies of the enterprise with vendor security policies, governance and legal issues, data distribution across multiple vendors. The main threat enterprises face in cloud computing are attacks by hackers can lead to loss of confidentiality, integrity or availability of data. The SLA should have clear answers to how cloud vendors will deal with security and legal issues, polices, asset control, data transfer and deletion, business continuity, backups and security policies.

SECURE MEASURES FOR CLOUDS

Many organizations are increasingly shifting to the cloud due to advantages as low maintenance and savings in cost. Gartner, Inc. had predicted that sales of global cloud services would grow 16 percent between 2009 and 2010, from$58.6 billion in 2009 to $68.3 billion in 2010 and global cloud services revenue would be about $148.8 billion in 2014 (Korzeniowski, Jander, 2009). With this tremendous growth for cloud computing, security is important for continued success of cloud. In a recent survey (Korzeniowski, Jander, 2009) by Information Week security concerns ranked highest in use of cloud. Poor secure measures could impede growth of clouds. Each cloud vendor has different security procedures. Maturity models are one way to measure progress of a security program (Creese, Hopkins, Pearson and Shen, 2009). How can an organization determine if the vendor it plans to use for cloud services is secure? Enterprises need a way measure security offered by vendors. Currently there are maturity models available as, COBIT maturity model, SSE-CMM model, CERT/CSO Security Capability Assessment model. These models need to be customized specifically for the organization and hence it is difficult to compare results from one organization to another (Chapin, Akridge, 2005) .These models focus on program elements from engineering or project management background. The approach use in this research is toward a detailed security maturity model called the Security Program Maturity Model and has a management systems approach. It follows the ISO 17799 standards for developing a complete security program and it involves the existence or number of elements.

INFORMATION SECURITY MANAGEMENT FRAMEWORK ISO 27002

The International Organization for Standardization (ISO) is a worldwide federation of national standards bodies from more than 140 countries. ISO 17799 is an international security standard that has been published by the ISO (International Organization for Standardization) and the IEC (International ElectroTechnical Commission). ISO 17799 provides a comprehensive security framework and was updated to ISO/IEC 27002 which has many controls within 12 security control clauses and 39 main security categories (ISO/IEC 27002:2005 , 2010). The controls not organized in any specific criteria are listed in Table I (Chapin, Akridge, 2005). ISO/IEC 27002 does not provide details on implementation and does not guarantee complete security using the controls. ISO/IEC 17799, IS 20072 offers guidelines and general principles for improving information security in organization. ISO 17799 does not have mandatory requirements. Each control should be given equal importance.

Table: ISO/IEC 27002 CATEGORIES

Overall security management	Communications and operations management
Asset classification and control	Organizational security
Human resources security	Business continuity management
Physical and environmental security	Compliance
Access control	Information security incident management
System development and maintenance	Risk assessment and treatment

ISO/ IEC 27002 FRAMEWORK FOR CLOUD COMPUTING

This research analyzes the ISO/IEC 27002 framework when enterprises use services of cloud vendors. The ISO framework includes the three categories: organizational infrastructure, technical infrastructure and information protection listed in Figure 1. Figure 2 lists the categories included in each of broad categories.

Figure 1: ISO/IEC 27002 Broad Categories

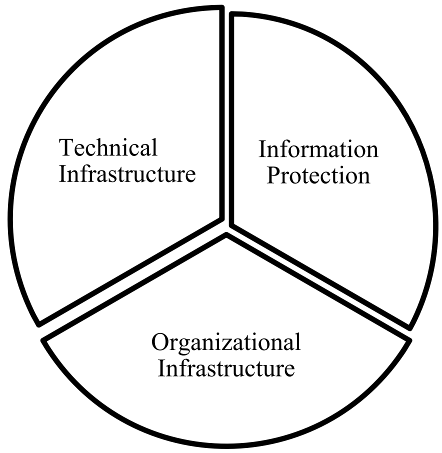
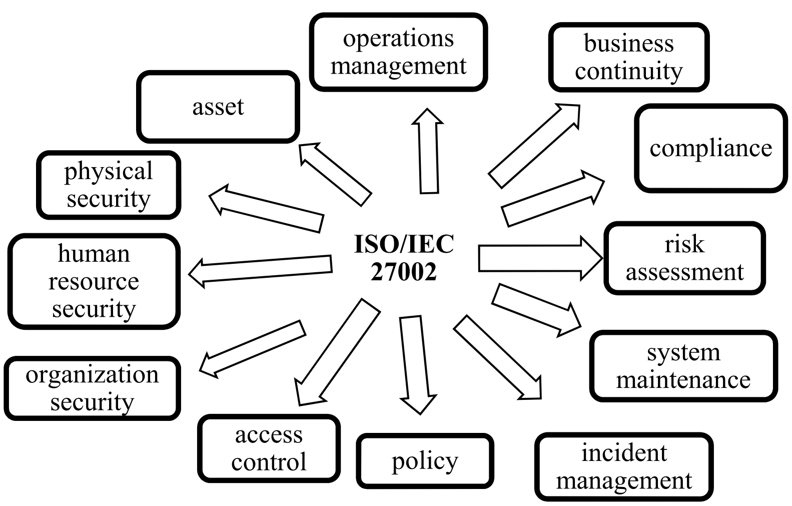


Figure 2: ISO/IEC 27002 Categories



The Organizational Infrastructure

Organizational Security

The cloud vendor must manage the security processes efficiently. The vendor must have suitable information system governance procedures specified in the service level agreements.

Asset Classification and Control

Assets of the enterprises must be specified in the SLA and can include files software, data and the enterprises need to be sure that vendors protect their assets and provide them with appropriate level of security. The vendor or sub vendors must perform periodic evaluations to ensure that asset control procedures are effective.

Information Security Policy

The cloud vendor must include security policies in the SLA .The policy should include description and review of the information security document. The policy must be comprehensive supported by a range of documentation covering standards and the guidelines.

The Technical Infrastructure

Access control

Vendors must have ways to detect unauthorized activities and provide security for remote access of data. The vendor must protect against threats by controlling access to networks, operating systems and applications by enforcing access control policies that must be specified in the SLA.

Systems Development and Maintenance

The SLA must ensure the security of the network, confidentiality and integrity of information. The vendor must take efforts to maintain security of software for enterprises that use the cloud.

Communications and Operations Management

Security procedures must be built into network operations to prevent damage to assets and disruption of business activities. The cloud provider must maintain documented operating procedures for information systems, protect against malicious code and protect network services in agreement with SLA.

Physical and Environmental Security

Enterprises need cloud vendors to manage physical threats and use appropriate security controls to prevent theft of information. The location of data is unknown in the cloud and facilities should be located in secure physical and environmental facilities.

Information Security Incident Management Information security incidents should be properly managed and there should enterprise and vendor agreements in managing incidents.

Information Protection

Human Resources Security

Enterprises need to make sure that cloud vendors follow policies and procedures in hiring administrators and users. Training must be provided to users so they can respond to security incidents in an effective way. The vendor and enterprise must be aware of policies in each region if the data are in different regions. The enterprise and the vendor must take steps to protect assets and these must be followed by all sub vendors.

Business Continuity Management

Business continuity plans ensure continuity of business operations when major disasters affect the critical processes in an organization. The dynamic cloud computing environment involves security risks and vendors must understand the business continuity needs differ in enterprises. The enterprise must have independent plans for backups, migration to other cloud providers in event of disasters.

Compliance

Enterprises need to comply with legal requirements, security standards and regulations. The use of cloud computing makes it hard to achieve compliance as the security policies of the enterprise may differ from that of cloud provider.

Risk Management

Vendors must identify, describe and rank risks in order in compliance with the enterprise. Risk management should include the risk analysis and risk evaluation. The elements of the ISO/IEC 27002 categories can be classified into different levels to makes the model effective. Table 2 shows the four distinct levels which are defined with increasing protection (Eloff & Eloff, 2003).

Table 2: Levels of Protection

Level 1: Low no effort made by vendor to implement controls	Level 2:Minimal minimal effort by vendor to implement controls	Level 3:Adequate adequate effort by vendor to implement controls	Level 4: High high effort by vendor to implement controls and effective cloud computing

CONCLUSION

Cloud computing is a growing field and many enterprises are shifting to clouds for ease of use and decreased costs. The impedance in using clouds for businesses is loss of control and inadequate security measures. Currently there are no effective metrics to measure security for cloud computing environments. This research applies the ISO/IEC 27002 framework for cloud computing. For further secure measures, the elements of this framework can be classified into different levels with varying protections. This is one of the ways enterprises can benchmark different cloud vendor services for doing businesses using cloud computing environment.

REFERENCES

Creese, S., P.Hopkins, S. Pearson, S. & Y. Shen (2009), Data Protection-Aware Design for Cloud Computing, *Proceedings of the 1st International Conference on Cloud Computing,* 119--130

Chapin, D. & S. Akridge (2005). How Can Security Be Measured? *Information Systems Control Journal*

Eloff, J. &M. Eloff, (2003). Information Security Management – A New Paradigm, *Proceedings of the 2003 annual research conference of the South African institute of computer scientists and information technologists on enablement through technology* (*SAICSIT)*, 130-136.

ISO/IEC 27002:2005 Information technology -- Security techniques -- Code of Practice for Information Security Management. Retrieved Dec 9, 2010 from http://www.iso27001security.com/html/27002.html#Section11

Korzeniowski, P., & Jander, M. (2009). Cloud Security, Information Week. Retrieved April 3, 2011, from http://www.informationweek.com/news/security/storage/showArticle.jhtml?articleID=221601449

Urquhart, J. (2008). A maturity model for cloud computing*, Cnet News website.* Retrieved March 15, 2010, from http://news.cnet.com/8301-19413_3-10122295-240.html