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Steven M. Zeltmann, Ph.D.
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Manuscripts

A NEURAL EXPERT SYSTEM WITH GOAL SEEKING FUNCTIONS FOR STRATEGIC PLANNING

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ABSTRACT

This paper presents a neural expert system approach to designing an intelligent strategic planning system. The main recipe of the proposed neural expert system is an inference mechanism capable of performing backwards. Four strategic planning portfolio models are considered: BCG matrix, Growth/Gain matrix, GE matrix, and Product/Market Evolution Portfolio matrix. The proposed neural expert system could provide "goal-seeking" functions, which prove to be very useful for unstructured decision-making problems, specifically in strategic planning. Goal seeking functions are realized through the backward inference mechanism, enabling the neural expert system to show the appropriate inputs (or conditions) to guarantee the desired level of outputs. To implement our idea, we developed a prototype system, named StratPlanner, which runs on Windows 2000. Using Korean automobile industry data, we performed experiments under competitively designed situations. Results support our supposition that the neural expert systems approach is useful for performing competitive analyses. Further research topics associated with the current research are also discussed.

INTRODUCTION

Recently, a number of researchers in Operations Research/Management Science (OR/MS) have attempted to build intelligent expert systems for solving a wide variety of problems including production scheduling, finance, personnel, marketing, accounting, etc. (Waterman, 1990). Common motivation underlying this research is to intelligently assist decision-makers who have to solve poor structure problems.

The strategic planning problem is one of many highly ill structured OR/MS problems. In today's business environment, organizations must define a plan for strategic problem solving. In broad terms, strategy is an articulation of the kinds of products the organization will produce, the basis on which its products will compete with those of its competitors, and the types of resources and capabilities the firm must have or develop to implement the strategy successfully (Oliver, 2001). Strategy, in effect, is the managerial action plan for achieving organizational objectives; it is mirrored in the pattern of moves and approaches devised by management to achieve desired performance. Strategy is therefore the "how" of pursuing the organization's mission and reaching target objectives (Thompson and Strickland III, 1990).

Today's managers must think strategically about their company's position and the impact of changing conditions. Organizations must monitor external situations very closely, to determine when the current strategy needs to be changed. They must understand the structure and dynamics of the industry in an effort to make any necessary organizational adjustments (Oliver, 2001). The advantages of successful strategic thinking and conscious strategic planning activities include: (1) providing better guidance to the entire organization on the crucial point of "what it is we are trying to achieve," (2) increasing management's awareness to change, new opportunities, and threatening developments, (3) providing managers with a greatly needed rationale for steering resources into strategy-supportive, results-producing areas, (4) helping unify the numerous strategy-related decisions by managers across the organization, and (5) creating a more pro-active management posture to counteract the tendency of decisions to be reactive and defensive. The decisive advantage of being pro-active versus re-active is the enhancement of long-term performance. Business history shows that high-performing enterprises often initiate and lead, not just react and defend. They see strategy as a tool for securing a sustainable, competitive advantage, and for pushing performance to superior levels.

Computer-based strategic planning systems play an increasingly relevant role in assisting both the diagnosis of strategic problems likely to threaten the organization's performance, and the suggestion of strategic alternatives to solve those problems. When designing such systems, certain objectives must be considered carefully. First, strategy analysts or managers in organizations should have access to reliable, low-cost, user-friendly instruments - for example, programs running on personal computers. Nevertheless, to meet strategy analysts' requirements, processing time should be relatively short. Since any failure of such systems could prove seriously harmful to an organization's competitive position and performance, both reliability and fault tolerance are crucial properties needing to be satisfied by such computer-based strategic planning systems. At the same time, the strategy analysts must be provided with as much information as possible about how the process is carried out.

In an effort to accomplish these objectives, developers of computer aids for strategy analysts face a variety of problems deriving from the complex nature of strategic planning-related data. Such data is characterized by an intrinsic variability, resulting from spontaneous internal mechanisms or a reaction to occasional external stimuli. Furthermore, most events related to strategic planning result from the interaction of many factors and sub-factors whose different effects are almost indistinguishable.

Strategy analysts are accustomed to such problems, but their skills cannot be easily incorporated into computer programs. Most strategic planning decisions are based on experience as well as on complex inferences and extensive strategic knowledge. Such experience and/or knowledge cannot be condensed into a small set of relations or rules, and this limits the performance of algorithmic approaches or conventional expert systems approaches to many strategic planning tasks. The breadth of strategic planning knowledge is therefore, an obstacle to the creation of symbolic knowledge bases, (for example, IF-THEN rules) comprehensive enough to cope with the

diverse exceptions that occur in practice. Experience-based learning, fault tolerance, graceful degradation, and signal enhancement are properties of neural networks that make the neural network-assisted expert systems effective in solving strategic planning problems. This points to a way for implementing reliable computer-based strategic planning systems that can closely emulate a strategy analyst's expertise.

This paper presents the basic part of a prototype neural expert system for diagnosing strategic problems, and suggests strategic alternatives that seem appropriate for current competitive situations. We will focus on two main issues: (1) the design of a neural expert system which is suitable for performing "goal-seeking" analysis and (2) the competence of neural expert systems-driven strategic planning process in real strategic planning situations. Section 2 briefly discusses a basic theory of strategic planning and neural networks. Strategic planning techniques that are used in this paper are introduced in Section 3. Backward inference mechanism is presented in Section 4. In Section 5, architecture of a prototype system is presented. In Section 6, the performance of a prototype system is illustrated with extensive experimental results in the Korean automobile industry. This paper ends with concluding remarks in Section 6.

STRATEGIC PLANNING AND NEURAL NETWORKS

A survey of the huge volume of contemporary practical and theoretical literature on neural network analysis yields the following three observations: (1) There exists a great variety of viewpoints and approaches to neural network analysis (2) A general design principle that will help determine an appropriate architecture of neural networks for a particular application does not exist. It varies with the characteristics of applications (3) Major emphasis has been put upon experimental results obtained from extensive simulations, not upon rigorous theoretical derivations or proofs. These general observations also prevail in neural network applications to OR/MS topics. Literature reporting the neural network applications to the OR/MS problems has begun to appear since the late 1980s. White (1988) suggested a neural network analysis for economic prediction using the IBM daily stock that returns data. Some neural network studies were performed to analyze a stock market prediction (Kamijo & Tanigawa 1990; Kimoto & Asakawa 1990). A current example includes the implementation of a neural network in the strategic planning of a major food industry leader in Taiwan (Chien, Lin & Tan, 1999). In addition, investors have begun using neural networks for currency exchange rate systems, in particular, the UK pound/US dollar exchange rate (Zhang & Hu, 1998). Nevertheless, few studies still exist that use neural networks for solving strategic planning problems.

In a broad sense, neural networks utilize data mining, fuzzy logic, mathematics and software agents in an effort to differentiate technical patterns (Lang, 1999). Neural networks have useful properties such as generalization capability, graceful degradation, heuristic mapping, fault tolerance, multiple inputs, and the capacity to treat Boolean and continuous entities simultaneously (Gallant 1988; Zeidenberg 1990). These vital properties ensure organizational strategy and data are

replenished, and rules are redefined (Lang, 1999). Accordingly, the neural networks seem highly suitable for handling strategic planning problems that are characterized by their unstructured nature and uncertainty.

STRATEGIC PLANNING TECHNIQUES

Before strategies can be planned, there must be a sense of organizational-wide innovation. There are four distinct phases that make up an organization's innovation: (1) strategy development, (2) ideation, (3) evaluation, and (4) implementation (Buggie, 2001). Once innovation has been implemented, strategic management planning can begin. Figure 1 depicts the process of strategic management, which consists of four basic elements: (1) environmental scanning, (2) strategy formulation, (3) strategy implementation, and (4) evaluation and control (Wheelen and Hunger, 1992). These processes, in conjunction with the four phases on innovation, create the foreground for a variety of strategic techniques. A number of these techniques have been proposed in previous studies (Abell & Hammond 1979; Glueck 1980; Larreche & Srinivasan 1982; Porter 1980; Rowe, Mason & Dickel 1982). Among them, knowledge-based strategic planning approaches were well reviewed in (Lee 1992; Mockler & Dologite 1991).

Figure 1.
Basic Elements of the Strategic Management Process

| Environmental Scanning | Strategy Formulation | Strategy Implementation | Evaluation and Control |
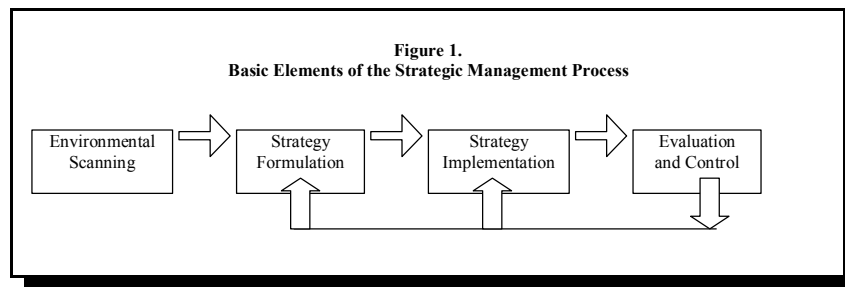
The available methods for strategic planning in literature can be classified into three categories, depending on their focus: (1) portfolio models, (2) profit impact of market strategy (PIMS) analysis, and (3) growth vector analysis. Refer to Rowe, Mason, Dickel (1982) or Lee (1992) for details about these three categories. Portfolio models assist managers in choosing products that will comprise the portfolio and allocate limited resources to them in a rational manner. PIMS analysis is designed not only to detect strategic factors influencing profitability, but also to predict the future trend of return on investment (ROI) in response to changes in strategy and market conditions. Growth vector analysis adopts the idea of product alternatives and market scope to support the product development strategy. This creates the possibility of linking both strategic and international perspectives together. In turn, the organization can build an assurance that relevant business alternatives are considered, strategies are compatible and evaluation/implementation procedures are simplified. The end result lists three strategies that are penetrating a market further

with its present products: imitating competitors, introducing current product variants, and innovating entirely new products.

   We choose four strategic evaluation methods from portfolio models: BCG matrix, Growth/Gain matrix, GE matrix, and Product/Market Evolution Portfolio matrix. The reasons are: (1) portfolio models have been widely acknowledged among researchers and practitioners and, (2) the four strategic methods selected can provide most of the information that might have been expected from the PIMS analysis and growth vector analysis. The BCG matrix is the single, most popular method. It emphasizes the importance of a firm's relative market share and industry growth rate, and displays the position of each product in a two-dimensional matrix. A more recent adaptation of the BCG matrix is the Mission and Core Competencies (MCC) matrix. The MCC matrix can be utilized to monitor and emphasize claims on all organizational resources (John, 1995). While this adds significant development towards the efforts of strategic planning, the MCC matrix needs to be researched, tested and implemented further. Therefore in this paper, we focus on the heavily researched strategic planning matrix, the BCG matrix. The products within a BCG matrix are called "Stars" "Cash Cows" "Question Marks or Problem Children" and "Dogs" by their position in the matrix as shown in Figure 2.

Figure 2
BCG Matrix

		Stars	Question Marks
Industry Growth Rate	High		
	Low	Cash Cows	Dogs
	0	High	Low

Relative Market Share
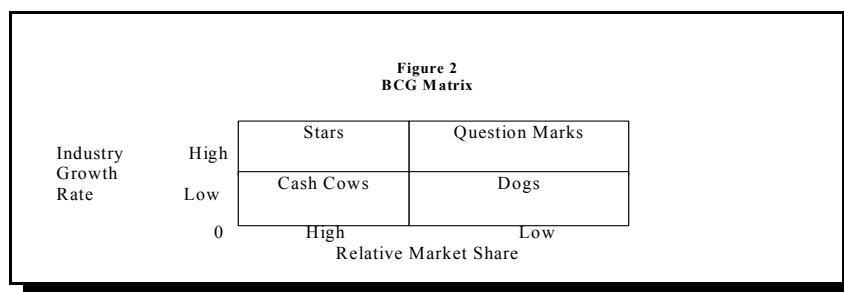
   Usually the highest profit margins are expected from "Stars," but they are also likely to require high net cash outflows in order to maintain their market shares. Eventually, "Stars" will become "Cash Cows" as growth slows down and the need for investment diminishes as they enter the maturity stage of the product life cycle. "Question Marks or Problem Children" require large net cash outflows to increase the market share. If successful, these products will become new "Stars", which will eventually become the "Cash Cows" of the future. If unsuccessful, these products will become "Dogs" and excluded from the product portfolio. The BCG matrix alone, however, is not sufficient to make the investment decision because the model is too simple to cover all aspects of decision-making. Perhaps the MCC matrix would be more appropriate due to its ability to access numerous organizational resources. Regardless, in many circumstances, factors other than relative market share and industry growth rate play a significant role in production strategy formulation. To compensate for the weaknesses of the BCG matrix, the Growth/Gain matrix, the GE matrix, and the Product/Market Evolution Portfolio matrix are used as well.

The Growth/Gain matrix indicates the degree of growth of each product against the growth of the market (see Figure 3). Product growth rate is plotted on the horizontal axis and market growth rate on the vertical axis. Share gaining products appear below the diagonal line while share-losing products appear above it. Products on the diagonal line are interpreted as holding the current market share. Alternatively, the graph displaying the trends of the products sales compared with market size may replace the role of the Growth/Gain matrix in a simpler way (Lee 1985).

Figure 3
Growth/Gain Matrix

Share Losing Product

Market Growth Rate

Product Holding Share

Share Gaining Product

Product Growth Rate
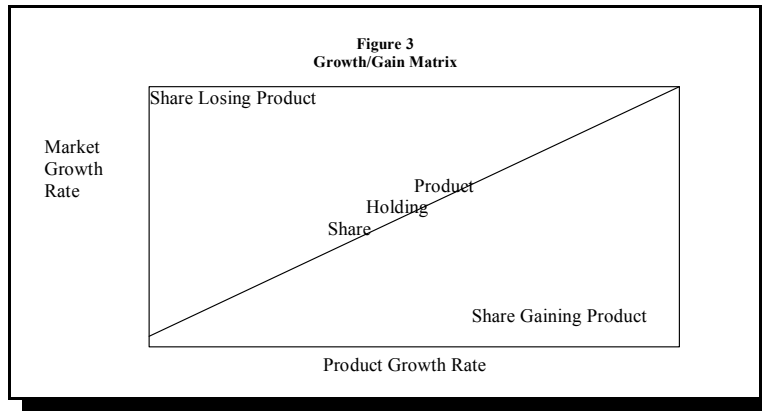
The composite measures of market attractiveness and business (product) strength are plotted in the GE matrix. In order to construct the GE matrix, managers have to select the relevant factors having significant relationship with industry attractiveness and business (product) strength of the firm. Next they assess the relative weights of those factors depending on manager's judgment, combining the weights to depict composite measures on the GE matrix. Figure 4 shows a 3 x 3 GE matrix chart depicting relative investment opportunity.

Figure 4
GE Matrix Chart

Industry Attractiveness		Strong	Medium	Weak
	High	Winners	Winners	Question Marks
	Medium	Winners	Average Business	Losers
	Low	Profit Producers	Losers	Losers

Business Strength/Competitive Position
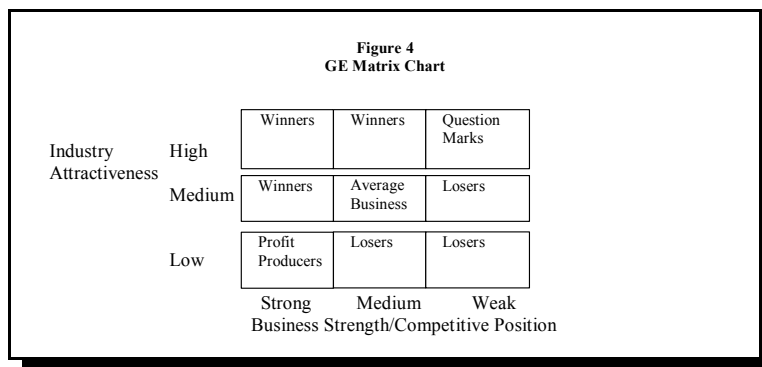
Strategic managers may decide the overall direction of the firm through its corporate strategy by combining market attractiveness with the company's business strength/competitive position into a nine-cell matrix similar to the GE matrix (Wheelen and Hunger 1992). The resulting matrix, depicted in Figure 5, is used as a model to suggest some alternative corporate strategies that might

apply to the company's situation. Cells 1, 2, 5, 7, and 8 suggest that growth strategies are either concentrated, which signifies expansion within the firm's current industry, or diversified, where growth is generated outside of the firm's current industry. Cells 4 and 5 represent stability strategies, which are a firm's choice to retain its current mission and objectives without any significant change in strategic direction. Cell 3, 6, and 9 display retrenchment strategies, which are the reduction in scope and magnitude of the firm's efforts.

Figure 5
Contingency Corporate Strategy (Wheelen and Hunger, 1992)

Business Strengths/Competitive Position

		Strong	Average	Weak
Industry Attractiveness	High	1. Growth Concentration via Vertical Integration	2. Growth Concentration via Horizontal Integration	3. Retrenchment
	Medium	4. Stability Pause or Proceed with Caution	5. Growth Concentration via Horizontal Integration Stability No Change in Profit Strategy	6. Retrenchment Captive Company or Divestment
	Low	7. Growth Concentric Diversification	8. Growth Conglomerate Diversification	9. Retrenchment Bankruptcy or Liquidation

The GE matrix does not depict as effectively as it might the positions of new businesses that are starting to grow in fledgling industries. In that case, Hofer and Schendel (1978) proposed to use a Product/Market Evolution matrix in which businesses are plotted in terms of their relative competitive position and stage of product/market evolution. It is vital that organizations prepare themselves for all potential stages of the business life cycle, whether the market initiates a technology push or demand-pull. In an effort to meet these competitive stages, the product matrix proposes four main strategies: (1) sub-contracting, (2) cooperation, (3) networking, and (4) joint research (Maisseu, 1995). They also recommended investment strategies at the business level. See Figure 6. The combined use of these four strategic models can provide most of the functions necessary to effectively evaluate corporate and/or business strategies.

Figure 6
Product/Market Evolution Portfolio Matrix and Investment Strategies

Relative Competitive Position

		Strong	Average	Weak	Drop-Out
Stage of Market Evolution	Development Shake-Out	Share – Increasing Strategy			Turnaround Or Liquidation Or Divestiture Strategies
	Growth	Growth Strategy			
	Maturity Saturation Petrifaction	Profit Strategy		Market Concentration and…	
	Decline	Asset Reduction Strategy			

Source: Hofer and Schendel (1978)

INFERENCE MECHANISMS

The multi-phased aspects of strategic planning activities described above indicate that the one-shot, or wholesome approach is not appropriate for effective strategic planning. Rather, to simulate a strategy analyst's reasoning as closely as possible, it would be better to divide the strategic planning-related decision-making processes into a small, relevant number of sub-processes. In this respect, we propose forward inference and backward inference mechanisms to suggest more robust strategies. Forward inference process helps decision-makers perform "what-if" analyses, which are essential for diagnosing the strategic problems and preparing strategic policies against the uncertain future. Backward inference processes provide "goal-seeking" supports that are also useful for decision-makers to accomplish given strategic goals through more effective strategies. In addition, a few studies have researched and implemented a new proposal mechanism for neural networks application. The scenario generator, which is based on both the neural networks theory and the theory of truth value flow inference, possesses the skills to learn and correct organizational mistakes (Li, Ang & Gay, 1997). In theory, this would create the "Ivory Tower" for strategic planning problem solving. However, the studies are few and the available evidence remains inconclusive to warrant any replacement of current mechanisms with the scenario generator. Therefore, this paper strictly focuses on the goal-seeking functions and backward inference process. See Figure 7.

After training the RCP, CCS and GBS neural network modules with appropriate training data, three sets of neural network knowledge base are generated; RCP knowledge base, CCS knowledge base, and GBS knowledge base.

Figure 7
Overall Diagram

Input Data	Backward Inference	Output
	Neural Expert System	
	Goal-Seeking Functions	
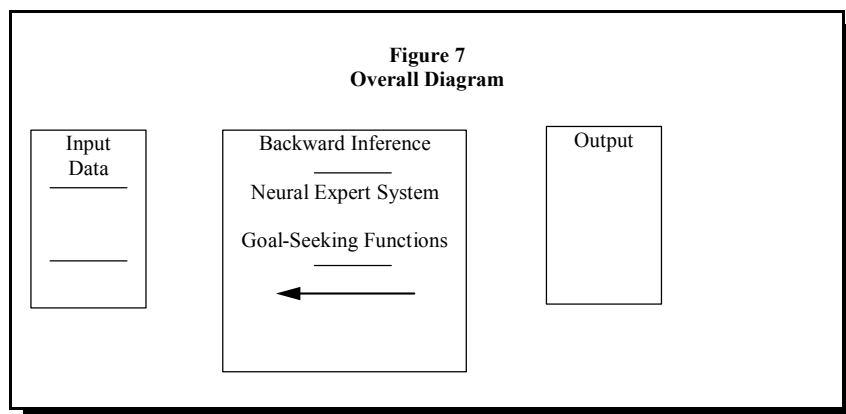
Expert's knowledge are stored in a conventional knowledge base which may include information about various topics, for example, industry environments, socio-economic situations, contingency corporate strategies, competitive position objective, and investment strategy with respect to various strategic situations, etc. Especially, we consider in this paper expert knowledge related to three kinds of areas: contingency corporate strategies, competitive position objective, and investment strategy. Contingency corporate strategies include nine types of strategies: "concentration via vertical integration", "concentration via horizontal integration", "concentric diversification", "conglomerate diversification", "pause or proceed with caution", "no change in profit strategy", "turnaround", "captive company or divestment", and "bankruptcy or liquidation." Each of the six generic types of business strategies involves a different pattern of competitive position objectives, investment strategies, and competitive advantages, which are summarized in Table 1.

Table 1 Characteristics of the Six Generic Business Strategies		
Type of Generic Strategy	Competitive Position Objective	Investment Strategy
Share-increasing strategies		
Development stage	Increase position	Moderate investment
Shake-out stage	Increase position	High investment
Other stages	Increase position	Very high investment
Growth strategies	Maintain position	High investment
Profit strategies	Maintain position	Moderate investment
Market concentration and asset reduction strategies	Reduce (shift) position to smaller defendable level (niche)	Moderate to negative investment
Liquidation or divestiture strategies	Decrease position to zero	Negative investment
Turnaround strategies	Improve positions	Little to moderate investment

Backward inference process provides information about the decision making company's positions in the BCG and Growth/Gain matrices. In the backward inference process, we propose three neural network modules: (1) contingency corporate strategy - relative competitive position (CCS_RCP) module, (2) generic business strategy - relative competitive position (GBS_RCP) module, and (3) relative market share - growth/gain (RMS_GG) module. In addition, stage of market evolution (SME) and industry attractiveness (IA) are also used as additional information to CCS and GBS neural network module. Each neural network module consists of one feed-forward neural network trained by the back propagation algorithm, as shown in Figure 8.

Figure 8
Backward Inference Diagram

CCS_RCP KB	GBS_RCP KB	RMS_GG KB

Neural Network Knowledge Bases

Conventional Knowledge Base

Final Conclusion

USER
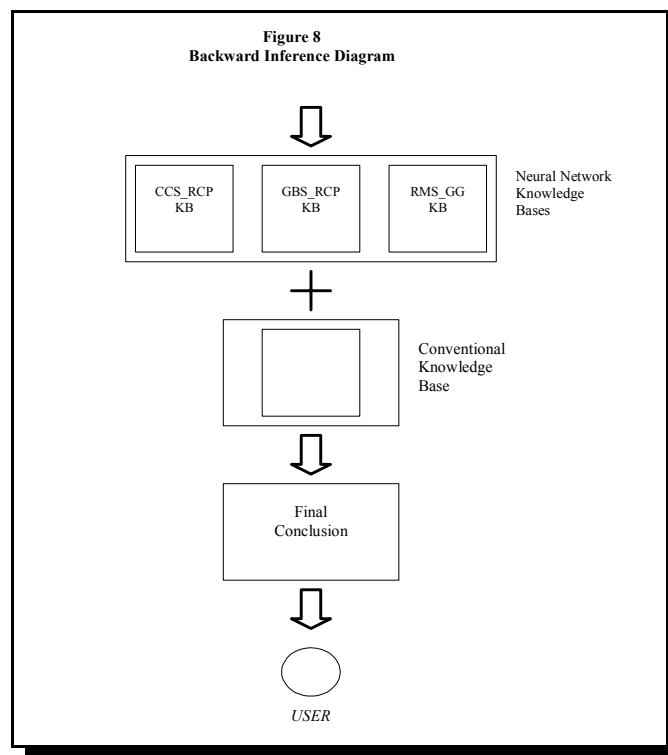
First, if one of the contingency corporate strategies is selected as a target strategy, the corresponding cell within the GE matrix is determined by a decision-maker. IA value is also determined. With this information, the CCS_RCP module provides information about the competitive position in the market relative to that of the target competitor. The architecture of CCS_RCP neural network module has 14 neurons in the input layer and 4 neurons in the output layer. Output of the CCS_RCP module is then used as input to the RMS_GG module. Figure 9 shows the architecture of the CCS_RCP module.

```
                        Figure 9
                CCS_RCP Neural Network Module

    Input Neurons:
            H-S Winners/ H-A Winners/ M-S Winners/ H-Average Businesses/
            L-Average Businesses/ Profit Producers/ Question Marks/
            M-W Losers/ L-A Losers/ L-W Losers
        IA Part ->High/ Medium-High/ Medium-Low/ Low
    Output Neurons:
            Strong/ Average/ Weak/ Drop-Out
```
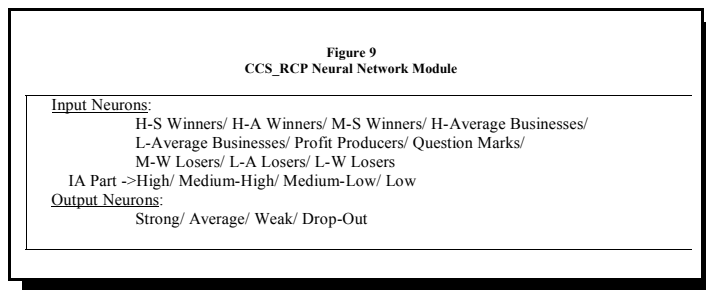
The input neurons of the GBS_RCP module require investment strategies as well as SME information. Output neurons of the GBS_RCP module are those of original RCP module such as Strong, Average, Weak, and Drop-out. The architecture is summarized in Figure 10.

```
                        Figure 10
                GBS_RCP Neural Network Module

    Input Neurons:
            Share Increasing/ Growth/ Profit/ Market Concentration and
            Asset Reduction/Turnaround/ Liquidation or Divestiture

    SME Part -> Development/ Growth/ Shake-Out/ Maturity/ Decline

    Output Neurons:
            Strong/ Average/ Weak/ Drop-Out
```
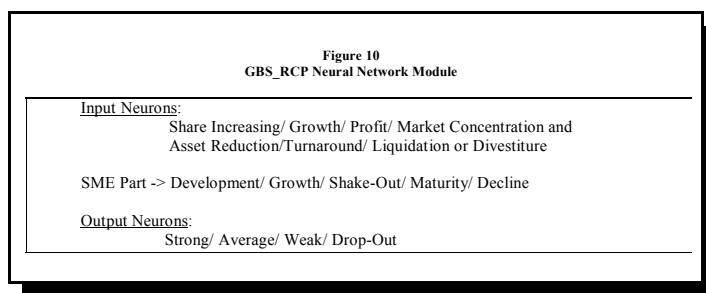
Finally, the input neurons of RMS_GG module require information about the output values of GBS_RCP or CCS_RCP, as well as information about the target competitor's BCG and Growth/Gain matrices. The output neurons of RMS_GG module are specific positions in the BCG and Growth/Gain matrices. Detailed information about the architecture of the RMS_GG module is shown in Figure 11.

```
                        Figure 11
                RMS_GG Neural Network Module

    Input Neurons:
                Strong/ Average/ Weak/ Drop-Out
        < Competitor >
        BCG         : Stars/ Cash Cows/ H-Question Marks/ M-Question
                      Marks/ L-Question Marks/ H-Dogs/ M-Dogs/ L-Dogs
        Growth/Gain: Share Gainer/ Share Holder/ Share Loser

    Output Neurons:
        < Decision Making Company >
        BCG         : Stars/Cash Cows/ H-Question Marks/ M-Question
                      Marks/ L-Question Marks/ H-Dogs/ M-Dogs/ L-Dogs
        Growth/Gain: Share Gainer/ Share Holder/ Share Loser
```

After training the CCS_RCP, GBS_RCP and RMS_GG module with appropriate training data, three kinds of neural network knowledge bases are generated; CCS_RCP knowledge base, GBS_RCP knowledge base, and RMS_GG knowledge base.

ARCHITECTURE OF A PROTOTYPE SYSTEM

We developed a prototype system running on Windows 2000. It is coded in Microsoft Visual C++ language. Its main menu is composed of five sub-menus as shown in Figures 12 and 13.

Figure 12
Structure of Main Menu in a Prototype System

Figure 13
Main Menu Screen
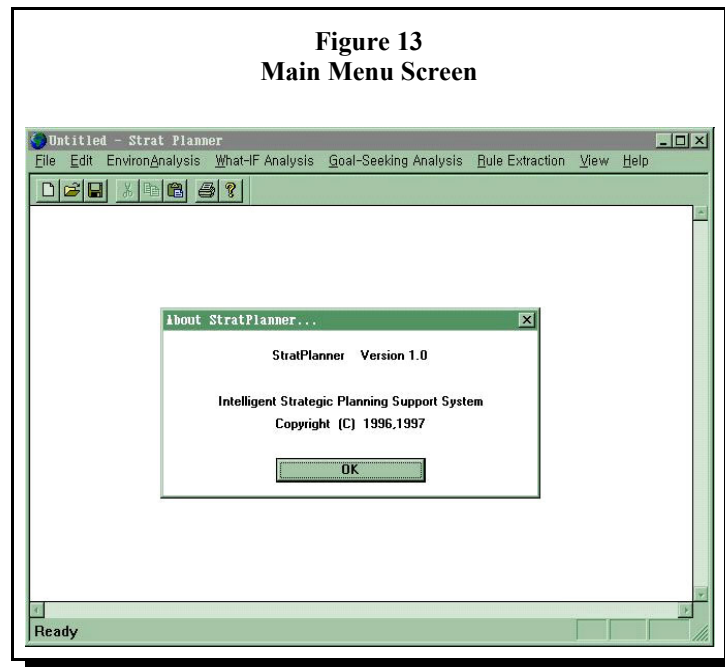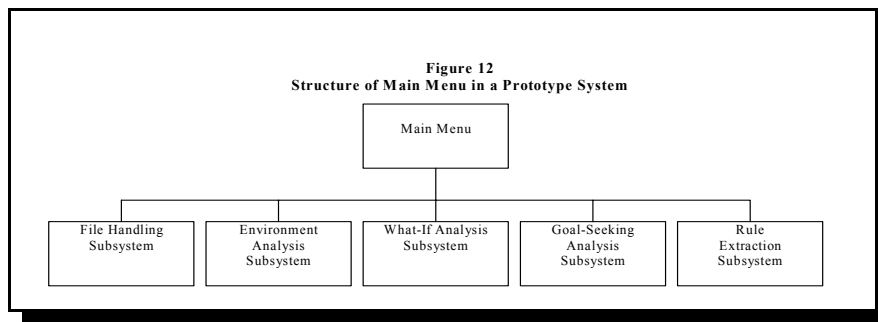
As mentioned in the introduction, we will illustrate the performance of backward goal-seeking analysis. Goal-seeking analysis is performed in the following steps summarized in Figure 14.

Figure 14
Steps of Goal-Seeking Analysis in a Prototype Neural Expert System

Stage 1: GBS-RCP/ CCS-RCP Stage

  Step 1. Select a target strategy from either GBS or CCS.
        Step 1-1. If GBS is selected,
                Step 1-1-1. Open the weight file of GBS-RCP neural network module.
                Step 1-1-2. Select a specific GBS strategy.
                Step 1-1-3. Input data about stage of market evolution.
                Step 1-1-4. Get the result from GBS-RCP neural network knowledge base.

        Step 1-2. If CCS is selected,
                Step 1-2-1. Open the weight file of CCS-RCP neural network module.
                Step 1-2-2. Select a specific CCS strategy.
                Step 1-2-3. Input data about industry attractiveness.
                Step 1-2-4. Get the result from CCS-RCP neural network knowledge base.

  Step 2. RMS-GG Stage.
        Step 2-1. Open the weight file of RMS-GG neural network module.
        Step 2-2. Input data about competitor's BCG and Growth/Gain matrix.
        Step 2-3. Get the result from RMS-GG neural network knowledge base.

REAL LIFE APPLICATION: AUTOMOBILE INDUSTRY IN KOREA

Experiments are performed with Korean automobile industry data, which is considered as a strategically turbulent market. The data is selected to show the performance of a prototype system in a turbulent strategic planning environment. Previous studies by H. Z. L. Li and Hu (2000) have defined such turbulent factors. They include the following: (1) incorrect work, (2) machine breakdowns, (3) re-work due to quality, and (4) rush orders. Table 2 depicts the categories of automobile data used in our experiments.

| Table 2: Categories of Korean Automobile Data			
Car Type	Company Name		
	KIA	HYUNDAI	DAEWOO
Small	Pride	Excel	Lemans
Compact	Capital Sephia	Elantra	Espero
Medium	Concord	Sonata	Prince
Large	Potentia	Grandeur	Super Salon

Monthly domestic sales data of three companies' passenger cars from May 1990 to August 1994, as well as miscellaneous strategic planning data from May 1990 to August 1994, was collected. The domain knowledge from two experts, a strategy analyst in 'K' automobile company and a strategy expert in a university are also used in this experiment. Table 3 shows the type and description of data used in our experiments.

Table 3: Type and Description of Data Used in Experiments		
	Type of Data	Description of Data
Quantitative Data	Monthly Sales Data	Market Growth Rate Relative Market Share Product Growth Rate
Qualitative Data	Expert Knowledge	Preparation of Input/Output Pairs used in Supervised Learning Preparation of Desired Output used in Test Knowledge related to three kinds of areas : Contingency corporate strategies Competitive Position Objectives by the typeof Generic Strategy Investment Strategies by the type of Competitive Position Objectives
	Data produced by Neural Network Modules	Relative Competitive Position Position in GE Matrix Position in Product/Market Portfolio Matrix Position in BCG Matrix Position in G/G Matrix
	User's Judgement	Determination of Stage of Market by Car Type Determination of Industry Attractiveness by Car Type Variable Selection Weight Determination

The data set consists of 52 cases divided into 32 cases from May 1990 to December 1992 for the training set and 20 cases from January 1993 to August 1994 for the test set. Another data set is arranged for the differences in production periods. Based on this data, we trained and tested RCP, CCS, GBS, CCS_RCP, GBS_RCP, RMS_GG neural network modules. By using monthly data, this experiment is assumed to be a monthly one-shot.

For illustration of backward inference, consider KIA as a decision making company. Suppose that KIA wants to examine "Profit" strategy for its small type car "PRIDE" comparing it to its competitor DAEWOO's "LEMANS" using data from January 1993. The stage of small car market evolution was analyzed as "Maturity". Using this information, GBS_RCP neural network knowledge base presents "Average" position as a minimum requirement condition. In the second stage, the competitive position of DAEWOO's "LEMANS" was analyzed to belong to "Middle-Dogs" in BCG matrix and "Share Holder" in Growth/Gain matrix, respectively. Based on the results

from GBS_RCP neural network knowledge base and the competitive position of DAEWOO's "LEMANS", RMS_GG neural network knowledge base provides that the minimum competitive positions of "PRIDE" for "Profit" strategy comparing to its competitor DAEWOO's "LEMANS" are "Middle-Dogs" and "Share Holder", respectively. The sample screen is shown in Figure 15.

Figure 15
Sample Result of Stage 2 Step 3 in Goal-Seeking Analysis
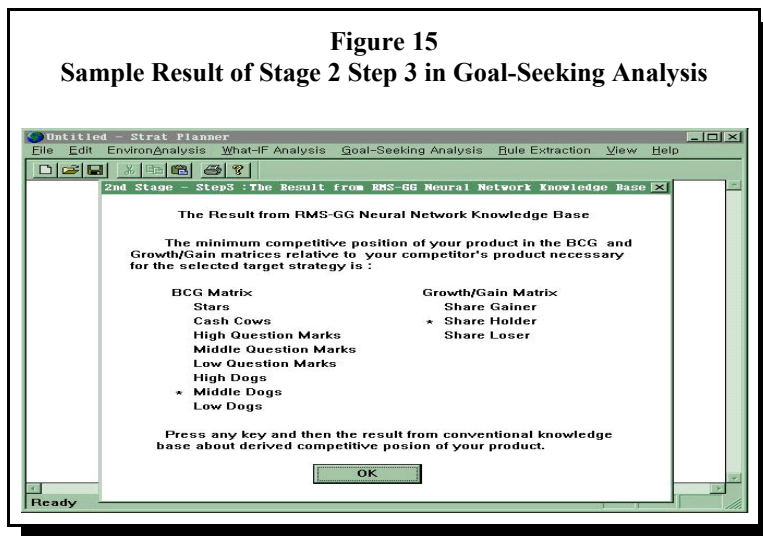
The current competitive positions of "PRIDE" comparing to its competitor DAEWOO's "LEMANS" are "High-Dogs" and "Share Loser". Therefore, the prototype system displays that the "profit strategy that you consider is adequate for current competitive positions of your product", which is illustrated in Figure 16. Table 5 summarizes the results with additional test cases.
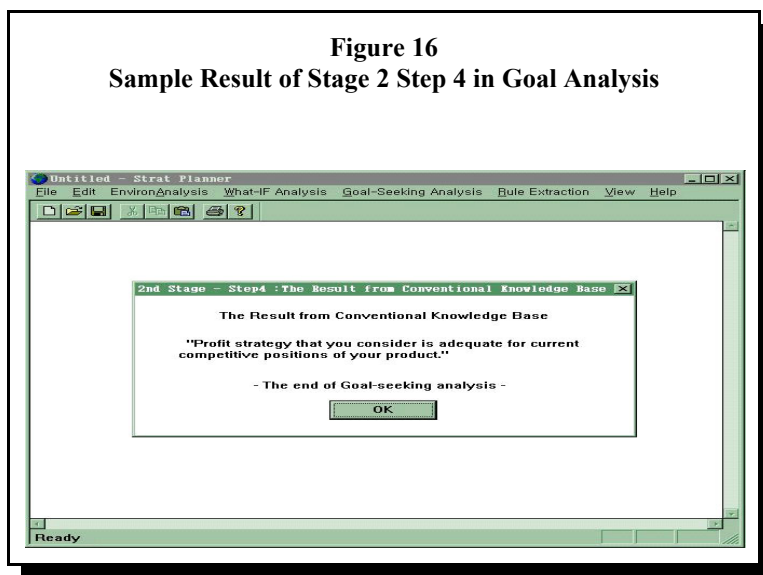

Figure 16
Sample Result of Stage 2 Step 4 in Goal Analysis

Table 4: Illustration of backward inferencing by GBS_RCP and RMS_GG neural network modules									
Test Set	GBS	SME	RCP	Competitor (DAEWOO's "LEMANS")		Decision Making Company (KIA's "PRIDE")			
				BCG	G/G	BCG		G/G	
						Actual	Desired	Actual	Desired
93.01	Profit Strategies	Maturity	Average	Middle-Dogs	Share Holder	Middle-Dogs	Middle-Dogs	Share Holder	Share Holder
02	Profit Strategies	Maturity	Average	Middle-Dogs	Share Loser	Middle-Dogs	Middle-Dogs	Share Loser	Share Loser
03	Profit Strategies	Maturity	Average	Low-Dogs	Share Gainer	Low-Dogs	Low-Dogs	Share Gainer	Share Gainer
04	Profit Strategies	Maturity	Average	Low-Dogs	Share Loser	Low-Dogs	Low-Dogs	Share loser	Share Loser
05	Profit Strategies	Maturity	Average	Middle-Dogs	Share Gainer	Middle-Dogs	Middle-Dogs	Share Gainer	Share Gainer
06	Profit Strategies	Maturity	Average	Middle-Dogs	Share Gainer	Middle-Dogs	Middle-Dogs	Share Gainer	Share Gainer
07	Profit Strategies	Maturity	Average	Middle-Dogs	Share Gainer	Middle-Dogs	Middle-Dogs	Share Gainer	Share Gainer
08	Profit Strategies	Maturity	Average	Middle-Dogs	Share Loser	Middle-Dogs	Middle-Dogs	Share Loser	Share Loser
09	Profit Strategies	Maturity	Average	Middle-Dogs	Share Loser	Middle-Dogs	Middle-Dogs	Share Loser	Share Loser
10	Profit Strategies	Maturity	Average	Middle-Dogs	Share Gainer	Middle-Dogs	Middle-Dogs	Share Gainer	Share Gainer
11	Profit Strategies	Maturity	Average	Middle-Dogs	Share Gainer	Middle-Dogs	Middle-Dogs	Share Gainer	Share Gainer
12	Profit Strategies	Maturity	Average	Middle-Dogs	Share Loser	Middle-Dogs	Middle-Dogs	Share Loser	Share Loser
94.01	Market Concentration	Maturity	Weak	High-Dogs	Share Gainer	High-Dogs	Middle-Dogs	Share Holder	Share Loser
02	Market Concentration	Maturity	Weak	Cash Cows	Share Gainer	High-Dogs	High-Dogs	Share Gainer	Share Gainer
03	Market Concentration	Maturity	Weak	Middle-QM	Share Loser	Low-Dogs	Middle-QM	Share Gainer	Share Loser
04	Market Concentration	Maturity	Weak	Stars	Share Holder	Low-Dogs	Stars	Share Holder	Share Holder
05	Market Concentration	Maturity	Weak	Cash Cows	Share Loser	High-Dogs	Cash Cows	Share Gainer	Share Loser
06	Profit Strategies	Maturity	Average	Low-QM	Share Loser	Low-QM	Low-QM	Share Loser	Share Loser
07	Profit Strategies	Maturity	Average	Cash Cows	Share Gainer	High-Dogs	Cash Cows	Share Gainer	Share Gainer
08	Profit Strategies	Maturity	Average	Low-Dogs	Share Loser	Low-Dogs	Low-Dogs	Share Loser	Share Loser

CONCLUDING REMARKS

In this paper, we proposed a neural expert system capable of performing a backward inference so that strategic planning problems may be solved more effectively. The proposed neural expert system is designed to provide a "goal-seeking" inference function, based on combining the generalization capability of neural networks with an expert system. A prototype system has been developed to prove our approach. Its performance was illustrated with real life data of the automobile industry in Korea. However, much room exists for further research. In this respect, we are currently developing an improved version of the prototype system by incorporating what-if analysis, refined mechanisms of environmental analysis, competitor analysis, and advanced strategic planning models.

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PASSWORD PITFALLS AND DYNAMIC BIOMETRICS: TOWARD A MULTI-LAYER USER AUTHENTICATION APPROACH FOR ELECTRONIC BUSINESS

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ABSTRACT

With the increased awareness of the dangers of cyber-terrorism and identity fraud, the security of information systems has been propelled to the forefront as organizations strive to implement greater access control. Access control for information systems is founded upon reliable user authentication, and the predominant form of authentication remains the username-password combination. There are several vulnerabilities associated with an over-reliance upon this method of authentication, stemming from weaknesses in both the user construction of passwords and single-layer authentication techniques. The growing number of Internet business transactions highlights the need for a more secure method of user authentication that is cost-effective as well as practical. A multi-layer user authentication scheme is proposed as a solution, incorporating the use of dynamic biometric data selection and a timestamp to guard against reuse of intercepted authentication bit streams.

INTRODUCTION

Computer-based information systems are becoming increasingly vital to the success of many businesses. As organizations move to adapt to the digital era, the quantity of confidential and sensitive data stored in electronic form on computers continues to increase at a blinding pace. The growing trend in customer relationship management and the need to offer personalization through customized information further adds to the wealth of data contained in these information systems. Since the compromise of the sensitive data stored in information systems can be disastrous for an organization, the security of these systems is of utmost concern.

The terrorist attacks of September 11, 2001 have served to propel security issues to the forefront, causing information systems managers to reanalyze their current methods of security and access control. In spite of these recent efforts, information system security remains surprisingly weak. The overwhelming majority of information system hacks and intrusions go unreported due to concerns over negative publicity, yet the few that are reported give a remarkably clear indication that hacking and cyber-terrorism are on the rise, annually causing considerable damage to organizations. At the core of this surge in information systems security breaches is a fundamental

flaw in the access control methods employed by most firms. The flaw lies in the over-reliance upon passwords as the primary, and in many cases the only, means of user authentication.

Given that "practically every penetration of a computer system, at some stage, relies on the ability to compromise a password," (Zviran & Haga, 1999, pp. 164) it seems rather surprising that passwords continue to form the basis of user authentication methods. In the password-based scheme, users of the information system are required to enter a username-password combination. The username establishes the identity of an individual as a valid user, and the password serves to confirm that identity and provide access to authorized resources (Proctor et al., 2002). Passwords are inherently weak security constructs due to the ability of hackers to guess them through brute-force methods enabled by the processing power of today's computers.

Despite their knowledge of the vulnerability posed by password-based user authentication systems, information systems managers continue to rely heavily upon single authentication using password-based access control because of its low implementation cost and end-user convenience. In the case of Internet web sites that require user authentication to provide personalized information or sensitive data, there does not appear to be a cost-effective alternative to the use of the username-password pair for access control. While major corporations have the financial ability to augment the security of their intranets and extranets through the use of smart cards and token devices, it is impractical and far too costly for business-to-consumer web sites to deploy this same technology. Such an effort would require the manufacture and shipment of a special token or smart card for every registrant on every web site. It is in this context of Internet transactions and electronic commerce (e-commerce) where the issue of information system security will be explored. The purpose of this study is to analyze in detail the inherent flaws in password-based user authentication and propose a solution to address how managers can effectively increase information system security and maintain access control through an improvement in the user authentication schemes at the root of current information security policy.

VULNERABILITIES OF PASSWORD-BASED USER AUTHENTICATION

Information security is concerned with enabling authorized users to access appropriate resources and denying such access to unauthorized users. The ability to authenticate valid users is therefore at the foundation of any access control system (Anthes, 1998). Passwords have long been the access control method of choice for most organizations, in part because of their low implementation cost and convenience to users. However, password-based authentication schemes have several vulnerabilities that render them unreliable for secure access control. These vulnerabilities can be attributed to the following three factors:

1. Several weaknesses in the construction of the password itself
2. The ease with which the password can subsequently be compromised
3. The lack of provable connection between a user and username

When juxtaposed with the tendency of individuals to reuse the same username-password combinations across several web sites, these factors reveal the lack of security offered by information systems that grant access based solely on the input of a valid username-password combination.

Weaknesses In Password Construction

First, the construction of the password itself often contributes to its weakness as a security mechanism. When passwords are generated by computer, they are generally more secure at the expense of being harder to remember (Zviran & Haga, 1993, 1999; Bishop & Klein, 1995). User-selected passwords, on the other hand, have the added benefit of being easier to recall, but are usually less secure in their construction. Case studies of real users over the past two decades reveal that characteristics of user-selected passwords have not changed significantly in response to publicity of information security breaches. According to a study by Morris and Thompson (1979), more than 85 percent of user passwords were dictionary words, words spelled backwards, names of people or places, or a sequence of numbers. Zviran & Haga (1999) further investigated the characteristics of user passwords, and examined issues such as password length, character composition, reset frequency, and the use of personal information as passwords. They conducted a survey of a sample of computer users by using an anonymous questionnaire that inquired about the users' password features. According to the study, they determined that the majority of passwords contained either five or six characters. Furthermore, their survey revealed the following:

> 71.9 percent of respondents' passwords were between one and six characters
> 80.1 percent of passwords were composed of strictly alphabetic characters
> 79.6 percent of respondents never changed their passwords
> 65.2 percent of respondents had used personal information in their password
> 35.3 percent of users wrote down their passwords nearby to remember them

The study conducted by Zviran &Haga (1999) echoes the findings of previous research on password security. Computer users tend to choose passwords that are short, constant, and based on their surroundings or personal information. Studies of user-selected passwords highlight that the common features of the passwords have remained fairly consistent over time. The underlying reason for this consistency is a matter of convenience for the end-users, who choose a password that will be simple and easy for them to remember. Hackers are undoubtedly aware of this trend and can subsequently focus their efforts to guess user passwords.

Ease of Password Compromise

The second vulnerability of the password-based user authentication scheme is the ease with which hackers can obtain these passwords. The common characteristics of the overwhelming

majority of passwords are the primary reason that passwords are easily compromised. Knowing that most passwords are short, alphabetic or alphanumeric strings of characters, hackers can run brute-force attacks that use dictionary words, proper names, and numbers to gain illegal access to information systems. Passwords can also be obtained by intercepting their transmission over communications channels, a technique known as "password sniffing" (Anthes, 1994). Given the findings of Zviran & Haga (1999) that over a third of users write down their passwords nearby, a password in this case "is no longer something to be guessed but becomes something to be located" (Porter, 1982). If an observer is able to see the user's password written down somewhere, or happens to see the user type the password, then the security of the password is subsequently compromised. Furthermore, despite creating passwords that are easy to remember, computer users are often faced with the burdensome task of remembering many passwords. As a result, users place repeated calls to help desks to obtain their password or to have it reset. An intruder with knowledge of a valid username can just as easily contact the help desk and obtain a working password, enabling him to then log in using the valid username-password combination.

Lack of Intrinsic Connection Between User and Username

The ability of invalid users to gain access to the resources of an information system as long as they log in with a valid username and password brings to light the third vulnerability of password-based user authentication methods. This third area of weakness lies in the lack of cohesion between a username and the actual user. The password-based user authentication method is founded upon the separation of valid username-password pairs from invalid pairs. If a valid combination is used, then the information system assumes that the appropriate holder of that combination entered the pair and thereby grants access to system resources and information.

The inherent problem with this approach, thus, stems from the inability of the system to "positively link the usage of the system to the actual user" (Ratha et al., 2001, p. 614), resulting in an information system whose resources are used by individuals with knowledge of valid usernames and passwords, but not necessarily individuals that are actually valid users. According to Jan and Tseng (1998), the user authentication process consists of the combined processes of identification and verification. When an individual enters a username, that individual makes a claim to be the proper bearer of that identity. Input of the corresponding password is all that is required to subsequently "verify" that identity as valid. Prior to granting access to information system resources, there is no further check by the system to ensure that an individual has made a valid claim on an identity.

The preceding three vulnerabilities of single authentication based on the use of passwords serve to illustrate that such a system should not be relied upon to protect the integrity of data in an information system. It is clear that additional measures are needed in order to enhance the security of an information system. There are several areas where attention should be focused to implement a more secure solution to user authentication.

These efforts can be categorized into the following areas:

1.   Construction of stronger user-selected passwords
2.   Alternatives to password-based authentication
3.   Combination of authentication methods

Each of these issues will be explored in more detail in an attempt to arrive at a cost-effective method of user authentication for business-to-consumer web sites.

STRONGER USER AUTHENTICATION TECHNIQUES

Construction of Stronger User-Selected Passwords

Although the password-based user authentication scheme has many vulnerabilities, it can be rendered more secure by simply making passwords more difficult to guess. User-selected passwords tend to be short, alphabetic or alphanumeric strings of characters. Shorter passwords can be cracked easily by running a brute-force attack or a password-cracking program such as "John the Ripper". In experimental tests, "John the Ripper" was able to correctly guess 75 percent of passwords when no guidelines were established for password length or composition (Proctor et al., 2002). In order to stand a chance against password-cracking programs such as this one, the first step one can take to create a stronger password is to add several characters to the password. As long as the password is still meaningful to the user, a password containing ten characters will be just as recallable for the user as a password of only five characters. And not surprisingly, Proctor et al. (2002) found that "John the Ripper" was only successful in guessing 17 percent of passwords containing at least eight characters.

While the extension of a password's character length will make it harder to hack by brute-force guessing, a password can be made even more secure if its character composition is extended. Users can expand the domain of possible characters to include uppercase letters, lowercase letters, numbers, and symbols (such as *, ^, or #), and should create their passwords using characters across the entire available character domain.

These recommendations for the creation of stronger user passwords have been publicized for quite some time. Nonetheless, users of information systems continue to engage in insecure password practices, creating passwords with the least number of allowable characters and using primarily alphabetic characters. It seems evident that users tend to avoid the creation of complex passwords if they can do so. A simple and cheap solution to this problem is the implementation of proactive password checking (Stallings, 1995). This concept uses software for the purpose of guiding users to create secure passwords. It works by enabling users to create their passwords but verifying that the selected passwords meet established criteria before they are assigned (Proctor et al., 2002). If a user attempts to create a password that does not meet the specified criteria for a

secure password, then the user is informed that the password is not acceptable and is asked to create a different password.

Proctor et al. (2002) conducted a series of experiments to measure the effect of proactive password checking. According to their study, the imposition of restrictions on password creation results in an increase in the amount of time and effort it takes a user to create a password that meets the criteria. They also noted that the amount of time it took users to subsequently log in to the system did not increase drastically, in part because the passwords they eventually came up with were still meaningful enough to remember.

Increasing the restrictions on allowable passwords will result in more complex, and therefore more secure, password construction. On the other hand, the use of a complexly constructed password will be rendered less secure when users undoubtedly fall back on the trend of re-using the same passwords for various web sites. Nonetheless, proactive password checking at the time of creation of user passwords can serve to ensure that all passwords in use have met the security guidelines established by the information system administrator.

Alternatives to Password-Based Authentication

The weaknesses associated with password-based access control can be overcome by taking advantage of alternative methods of user authentication. According to Lui and Silverman (2001), the following three categories can be used for authentication purposes:

1. Knowledge, "something you know"
2. Possession, "something you have"
3. Biometric, "something you are"

The first category includes information known by an individual, such as a password or personal identification number (PIN). The second category consists of an identifiable physical object that an individual possesses, such as a smart card, token, or identification badge. The third category, known as biometrics, includes biological attributes specific to an individual. The characteristics of each of these categories will be discussed in detail and are summarized in Figure 1.1.

PINs suffer from the same weakness as passwords in that they are easily guessed, and therefore should not constitute the only method of user authentication. Voice mail, for example, requires only a PIN to retrieve personal messages. Automated teller machines at banks, however, require a PIN in addition to the possession of a plastic card with information encoded magnetically.

The use of a card as an identification device has the benefit that a user must present the card in order to gain access to the information system. In order to present the card, the user must be in possession of the physical object itself. Under this method of user authentication, it is assumed that only a valid user will have an access card. However, cards as well as badges can be lost, stolen, damaged, or forged (Millman, 2001; Radcliff, 2002).

Figure 1.1: Categories of User Authentication			
Category of Authentication	Examples	Advantages	Disadvantages
Knowledge	PIN Password	Simple to implement Low cost Easy to reset if compromised	Easily compromised Easily forgotten Users may have to remember many of them
Possession	Token Badge Magnetic Card	Physically held by user Easily replaceable Low to moderate cost	Easily lost Easily stolen Users cannot access system if object is left at home
Biometric	Fingerprint Iris Retina Voice Signature	Very secure Cannot be forgotten or lost	Very costly Invasion of privacy concerns Possible discomfort from intrusive scanning More difficult to integrate

Cards and badges are much cheaper to produce and replace than tokens, which are small, portable devices that generally display a dynamic numerical password and cost up to $60 per token (Radcliff, 2002) and $2,000 to $17,000 for back-end servers (Anthes, 1994). Each token is synchronized with a central server, causing the token to always display the same numerical value that the server has stored for that token. The numerical password changes after a specified time interval in order to ensure that a password cannot be reused at a later time. There are already several token-based authentication technologies currently on the market, including Secure/IP and SecurID. Secure/IP, a product made by TGV, uses portable tokens in sync with a central server (Anthes, 1994). Security Dynamics, Inc. has a similar token-based product called SecurID that uses a random six-digit numerical password (Anthes, 1994). Token-based authentication has the advantage over password-based authentication that intercepted passwords cannot be reused because the password constantly changes. The disadvantages of tokens lie in their cost of implementation and the capacity for damaged, stolen, or misplaced tokens.

The third category of user authentication, called biometrics, involves an identifier that cannot be misplaced or forgotten (Liu and Silverman, 2001). Biometric devices use physical, biological features to identify and verify individuals. A biometric can take many forms, and in fact, any physical or behavioral characteristic of a person that can serve to uniquely identify that person can be considered a biometric. Examples include a fingerprint, hand geometric pattern, iris, retina, voice, signature, facial pattern, or even DNA (Liu and Silverman, 2001). Commonly accepted as evidence in law enforcement, a biometric is considered by many people to be the most secure method of uniquely identifying individuals.

Regardless of the specific type of biometric used, the first step in implementing a biometric-based authentication system is generally to store a template of the biometric data of a user.

Upon a subsequent attempt to access the information system, the user must present the required biometric identifier to a scanning or recording device, which then compares the input to the database of templates for a potential match. The need to store a biometric template for each user is, unfortunately, one of the major drawbacks of biometric-based authentication systems. Scalability becomes a major hurdle because the amount of time it takes a system to verify an individual increases significantly as more templates are added and checked against every input. Bandwidth likewise becomes a significant issue since the digitized data from biometric inputs can be quite large (Ratha et al., 2001).

Biometric-based authentication is considered to be extremely reliable, but like any authentication system, it is not foolproof. It is necessary for information systems managers to decide upon an acceptable balance between the false acceptance rate (FAR) and the false rejection rate (FRR) of a biometric system (Ratha et al, 2001). The false acceptance rate is a measure of what percentage of unauthorized users are granted access to the system due to similarities between the user and a stored template that are close enough to be considered a match. The false rejection rate, on the other hand, is a measure of the percentage of authorized users who are refused access, generally due to extraneous factors such as lighting or cleanliness variations of the subject.

Higher success rates of user identification may come at the expense of other disadvantages, however. While some biometric systems can read a user's input through a non-invasive method (such as signature recognition), other methods such as retinal scanning may seem somewhat uncomfortable for users. Furthermore, in the unlikely but possible event that biometric data is compromised, new biological features cannot be distributed to an individual as easily as passwords can be reset (Ratha et al, 2001). With their personal biometric data stored on servers, users are faced with the fear that their data will be compromised or their privacy violated. And finally, the financial cost of such a system cannot be ignored. Biometric systems are perhaps the most costly method of authentication to implement. Nonetheless, the additional security they provide must be factored into an analysis of their practicality and usefulness

Combination of Authentication Methods

User authentication controls, whether based on passwords, tokens, cards, or biometrics, provide a layer of security to information systems. However, each of these access control methods relies upon a single layer of authentication and can be compromised in a single step. The security of information systems can be increased through a technique called double authentication, which relies upon a combination of methods to perform user authentication and verification (Salkever, 2002). This technique is much more secure than access control based on single-layer authentication because even if one form of authentication is compromised, there is an additional check in place to prevent unauthorized access to information system resources.

Double authentication can take many forms. Several of these dual-layer systems have been in existence for quite some time, while other combinations are just emerging. Perhaps the most well

known double authentication technique is the use of a magnetic card along with a PIN known by the user. Banks have been using this dual layer of authentication at automated teller machines (ATMs) or with debit cards. This system incorporates something that the user possesses (the magnetic card) with something that the user knows (the PIN), thereby providing two layers of authentication before providing access to finances. Even in the event that an individual's debit card is stolen, the thief must also know the user's PIN for the card to be of any use.

The combination of a PIN and a possession is also utilized by most token-based access control systems. Instead of a magnetic card, users possess a token that displays a dynamic numeric access code. This code must be entered along with the user's PIN in order to gain access to the system. Token-based systems involving a token and PIN combination are slightly more secure than a magnetic card and PIN combination because the former also makes use of a timestamp to prevent password re-use. A timestamp is a date and time associated with the moment a password is entered by the user, and it must fall within the time specified by the server that a particular password is still valid. If a hacker, for example, knows the account number on a user's magnetic card and knows the user's PIN, he is able to compromise the system. On the other hand, even if a hacker is able to determine what number a user entered from the token and what number the user entered as a PIN, the hacker is unable to use that information to subsequently compromise the system since the number on the token will have changed.

Biometrics can even be used in conjunction with other forms of authentication to provide a greater degree of reliability. Lui and Silverman (2001) note the emergence of "hybrid technology" that encodes a user's biometric template on a smart card/sensor device. This device enables users to scan their fingerprint directly on a portable card, which compares the scanned information with the biometric data stored on the card. While biometrics offer increased security over other methods of authentication, this device can still be stolen and with it, an individual's biometric data. As mentioned earlier, the consequences of compromising a full biometric template are severe since an individual only possesses one set of fingerprints for life. In addition, the technology already exists to lift a fingerprint from a surface and manufacture a false finger capable of fooling some biometric sensors (Salkever, 2002). As a result, new biometric sensors are emerging that can detect the presence of a live finger by reading a pulse.

The biometric smart card is nonetheless a step in the right direction. Due to the storage of biometric data on the device itself, it is much faster than conventional biometric systems that store a user's biometric template on a server. When biometric data is stored on a central server, it takes a significant amount of time for the system to search every template in its database to find a match. As a result, some companies including Mastercard have implemented a system in which the user first indicates his or her name (which does not add much security), and that individual's biometric template is then retrieved from the database (Black, 2002). The individual then submits to a biometric scan that is compared with the template pulled from the database. Using this method, the system does not have to compare a scan with every template in the database.

Of all the forms of user authentication, biometrics is considered to be the most difficult to compromise. The combination of biometrics with alternative forms of authentication therefore seems to provide the most secure method of access control.

PROPOSED SOLUTION TO USER AUTHENTICATION FOR E-BUSINESS APPLICATIONS

Based upon the preceding analysis of access control technology, there is a need for a cost-effective, user-acceptable authentication method in the case of electronic business conducted over the Internet. Many businesses are web-enabling a significant part of their applications and enabling their customers to access sensitive information over the Internet, yet 99.5 percent of this electronic business does not offer any degree of security beyond a simple username and password (Radcliff, 2002). Granted, many web sites do not store personalized or sensitive information and merely require a username and password for registration purposes. However, in the case of online banking and other such transactions, the compromise of an account password can prove disastrous to a user. Internet transactions therefore require a completely novel approach to security.

The proposed solution to increase the security of Internet transactions in a cost-effective manner makes use of all three aforementioned categories of user authentication. This multi-layer authentication method combines the use of a PIN (something the user knows), a magnetic card (something the user has), and a biometric sample (something the user is). However, simply combining all three technologies will not solve the problem of secure user authentication unless it is cheap, versatile, and accepted by users. The proposed security solution satisfies all three criteria.

In order for this approach to be implemented, a small hardware investment is required on the user's end. Specifically, this proposal would require the use of a specialized keyboard that contained a USB card reader as well as a small fingerprint scanner. Such an approach would be very cost-effective because each web site wishing to conduct electronic business would not have to spend time and money to distribute tokens or smart cards to each user, and instead could take advantage of a technology that can be purchased once and used for all web sites.

The proposed solution will require each individual to have a username stored on a magnetic strip card. The username must be a unique string of both alphanumeric and symbolic characters and a recommended length of ten such characters, such as "m49K2g#%6L". This string must not contain as a substring the individual's name or social security number. Since the majority of Internet transactions take place with the use of a major credit card, it would seem logical to work with the credit card companies to add an individual's username to the data currently stored on the magnetic strip on a credit card. An individual would specify at the time of applying for a credit card if he desired that specific credit card to contain his username, and that card-issuing company would then create a username for the cardholder and encode it on the card. The credit card- username technique would not add any significant cost to the distribution of usernames, would be portable (in the user's

wallet), and would enable the user to maintain the same username across multiple sites, eliminating the need to remember multiple usernames.

Secondly, the user would select a PIN upon registering at each web site. This PIN will be known only by the user and not recorded anywhere. In addition, the user can choose to have a separate PIN for each e-business web site but can also securely use the same PIN for each site. This apparent security vulnerability warrants further explanation. The PIN would not be stored anywhere and would serve to tell the fingerprint scanner which bits of the user's scanned biometric reading to use for authentication purposes.

Combining each of these features, the proposed solution for secure user authentication during Internet transactions would work according to the following procedure. Upon registering at a web site, the user would first enter his username and then swipe the credit card encoded with the same username for initial verification. The user would then be prompted to scan his finger on the biometric sensor attached to the keyboard. The biometric scanner would detect whether a live finger or a fake has been presented as input by reading a pulse from the source. The digitized biometric data would only be stored locally for 60 seconds. During that time, the user would enter his PIN (the userPIN), and the web site would send a numeric value (henceforth labeled the sitePIN) as well as a timestamp. The PIN and the number sent by the web site would specify which combined bits of the biometric reading to use as the individual's password for that particular website, and this combination of biometric data bits (henceforth labeled the biopair value) would be sent back to the website with the user's timestamp. The biometric data sent to the website would only be a small portion of the user's full biometric reading, thereby maintaining the privacy of the actual biometric reading and avoiding the high bandwidth transmission of an entire reading. The timestamp would ensure that the biometric reading occurred within a specified time range after the request by the website was issued. This procedure is illustrated in Figure 1.2.

Each e-business web site would only be responsible for storing a username, sitePIN, and biopair value for each user, a feature that enables this multi-layer authentication technique to be completely scalable. Upon each subsequent visit to a site, the user would have to be authenticated and then permitted to perform any number of business-to-business or business-to-consumer transactions that are permitted for the specified user on that site. To perform each authentication, the site would query its database for the username and return the associated sitePIN to the biometric scanner. The user would once again scan his finger and enter his PIN, and the scanner would combine the bits of the biometric reading specified by the userPIN with the bits specified by the sitePIN. This combined value would be sent back to the web site, which would then compare this biopair with the biopair value in its database.

This multi-layer authentication technique solves a number of the problems with current methods of authentication. Privacy of biometric data is maintained and bandwidth resources are not overwhelmed since only a portion of the full biometric reading is sent over the Internet or stored in a web site's database. User PINs, which are known by the user and not stored anywhere, ensure that a user can specify which bits from his biometric reading to use as part of his password. This

technique enables a user to change his biometric site password at any time by merely changing his PIN. Even if a biometric transmission is intercepted, the timestamp ensures that the intercepted information cannot be reused, and the relationship of the biometric reading to the PIN ensures that the password can be changed if compromised. The problem with current biometric systems is that since the full biometric data is used for the comparison, a compromise of the data would be severe because a user has a limited number of fingerprints. Since each web site associates its own sitePIN with each user's biopair value, a password that is hacked from one web site cannot be used to gain access to other sites, even though the username is the same. This approach thereby enables users to use the same username and PIN for every web site without sacrificing security.

Figure 1.2
Proposed Dynamic Biometric Authentication Scheme
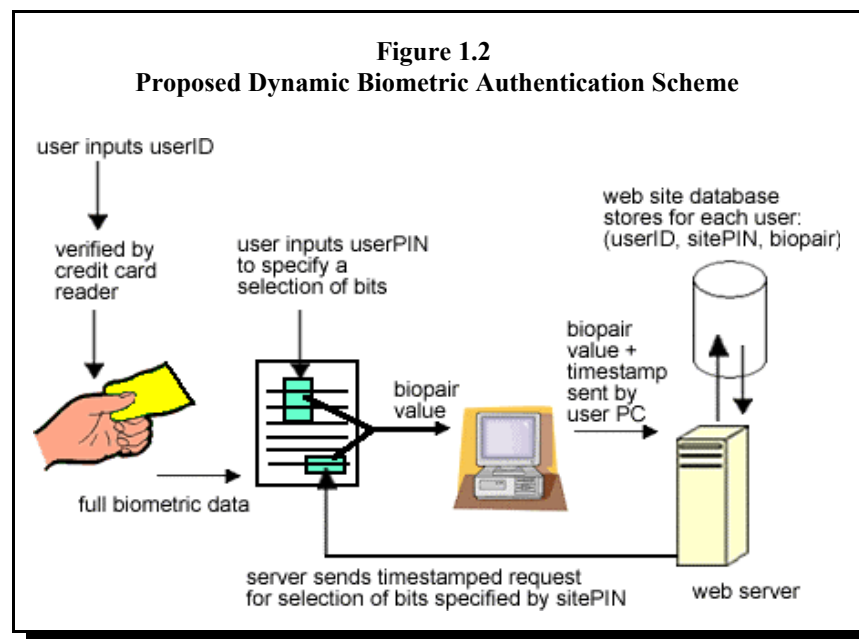
The downside to this technique lies in the added cost to the user in additional hardware functionality. However, this one-time cost is far outweighed by the increased level of security offered by this multi-layer authentication method. In addition, the keyboard scanner is extremely versatile in that it can be used for every e-business site that chooses to implement this security method. This increased level of security across all sites can therefore be obtained at a cost much less than if the user had to purchase a token or proprietary biometric scanner from each e-business.

CONCLUSION AND FUTURE RESEARCH

Passwords remain the most prevalent method of user authentication for information systems, and especially Internet transactions for e-business. Password-based authentication is lacking in security due to several factors contributing to the weakness of password construction and the ease

with which passwords can subsequently be compromised. The Computer Security Institute (2002) reported in its "Computer Crime and Security Survey" that 38 percent of responding corporations has security breaches resulting from unauthorized access to areas of their web sites. Alternative forms of user authentication, including tokens, smart cards, and biometrics, attempt to address some of the vulnerabilities of password-based systems, but suffer from their own vulnerabilities when employed in a single-layer authentication scheme. Double authentication techniques have been developed which combine the methods of two authentication techniques to increase the level of security of information systems. E-business transactions have yet to take advantage of increased security in user authentication methods due to the high costs associated with a large-scale deployment of double authentication technology by each individual site. The cost of increased security remains a principle inhibitor to its implementation, and the percentage of information technology budgets allotted to security has not kept pace with the increase in threats. In 2002, businesses reportedly spent only 11.8% of their information technology budget on security (Hulme, 2002). The multi-layer authentication method proposed in this study can increase the security of web-based transactions by providing a more reliable way to authenticate valid users and simultaneously reduce security implementation costs through the adoption of a single technology source usable by all e-business web sites.

While this study has laid the groundwork for a proposal to increase the security of Internet transactions, there are several areas that can be explored as further extensions of this research. Future study can look into the methods of authentication used by the 0.5 percent of Internet transactions identified as using more than strictly passwords (Radcliff, 2002). In addition, further research can analyze the multi-layer authentication method proposed in this study to determine its possible areas of vulnerability. And finally, the physical keyboard-scanner technology central to this proposal can be explored to reduce the cost of such a device and propel its mainstream user acceptance.

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RETURN-TO-SCALE IN PRODUCTION-SERVICE-DEMAND SYSTEM APPLICATION TO THE AIRPORT CONGESTION'S PROBLEM

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ABSTRACT

The concept of return-to-scale deals with production relationships over a period of time sufficiently long to allow changes in inputs. The paper describes a Production-Service -Demand (P-S-D) system, and its adjustment to a growing demand. The traditional return-to-scale concept does not apply.

The purpose of this paper is to describe the relationship between the inputs and the output of a P-S-D system - embodying several subsystems real-time connected - having to fulfill a growing task in a diligent manner, some subsystems' fixed assets being substitutable. Classic economies of scale concepts must be revised. Optimal system's configuration may be at the expense of some subsystems' owners, hence conflict of interest.

The problem of optimization of an airport-airline-market system is presented as one practical application. This optimization is not achieved today.

INTRODUCTION

The concept of return-to-scale deals with production relationships (i.e. output versus inputs), over a period of time sufficiently long to allow changes in any and all inputs, especially those inputs dealing with long-term capital commitments related to fixed assets. At the operational level, it is generally accepted that in expanding its scale of operation, as long as the market is not saturated, a firm might successively pass through a range of increasing return-to-scale (economies of scale) before reaching a range or point of constant return-to-scale, then arriving at a range of diminishing return-to-scale (diseconomies of scale).

The purpose of this paper is to show how the "return-to-scale" effect might affect a Production-Service-Demand system having to fulfill a growing task in a diligent manner. Given some growing demand forecasts, this paper explores the possibility of minimizing the total long-term cost of the system by "enlarging" some of the subsystems' assets, each asset having a different life expectation as well as a different owner. Such an investment decision requires then, some consensus between the sub-systems' owners benefiting of the decision made by one of them, to share in the cost of those benefits with the decider. Selfish search for subsystem optimization is

indeed not the answer, in a world submitted to global competition, where each subsystem has the right to survive, but cannot survive if the system to which they belong cannot survive.

RETURN-TO-SCALE CONCEPT

Strictly speaking, the expression "return-to-scale" refers to the character of change of the output, when all inputs are changed in equal proportion. Increasing return-to-scale (or economies of scale) is said to prevail if the rate of change of the output is larger than the rate of change of the inputs. If the rate of change in output is smaller, a diminishing return-to-scale (or diseconomies of scale) is said to be experienced. If the rate of change of the output is equal, a constant return-to-scale is said to be observed. However, the possibility of proportional change of all the inputs may only exist in the case of a linear homogeneous production function. Also by extension of meaning, the expression of "return-to-scale" nowadays, refers to the character of change of the output when inputs, reduced to a common denominator, with their cost in real dollar-terms, are modified and assorted appropriately. The cost of production of one unit of output versus the level of output is then the measure of the return-to-scale.

The concept is a key concern in production (Pratten, 1971). At the production level, economies of scale are conceptualized by the long run unit cost function, relating unit cost and planned output. This long run unit cost function reflects the locus of unit costs attainable by building production systems of various sizes and actually operating them in the neighborhood of their planned output. Before describing what is a Production-Service-Demand system, a summary of the main properties of the economies of scale concept applied to production is presented:

In a production system, there is a range of increasing return-to-scale
This range of increasing return-to-scale precedes any other types of return-to-scale
The market demand is larger than the envisaged production output
The output is always defined as scalar (one dimension)
The demand is not one of the inputs
The output level is not related to the locations of the demand
The output is not real-time related with demand.
The cost of delivery, when part of the problem, is proportional to the distance.

ECONOMIES OF SCALE CONCEPT WITH MULTIDIMENSIONAL OUTPUT

Many studies (Dicer, 1971; Johnson, 1970; Patton, 1970; Rakowski, 1977; Smith 1973) were undertaken on the application of the concept to transportation, especially in trucking operations. Authors Coyle, Bardi & Covinto, 1990;Glaskowsky Hudson & Ivie, 1990) agree that overall, in the long-term, economies of scale do not appear to be significant in motor carrier transportation. Economies of scale studies in transportation indeed focused their attention on

carriers' fleet size (Rakowski, 1971), mergers (Smith, 1973), sales volume at the micro level indeed, but with no concern on the market characteristics such as a task to be performed in a timely fashion.

In the transportation domain, a task achievement is a timely fulfillment of demands over a given territory, and a task force is the fleet required to meet the demand. A previous study (Milhomme, 1992) did underscore the fact that any enlargement of the task force had a negative impact on the task force's efficiency. This study focuses on the application of the economies of scale concept for a air carrier (airline) or a group of air carriers (airlines), assuming the responsibility to proportion their task forces and their output capability to a growing demand, in a timely fashion.

When dealing with a production-service-demand system, one structural problem is the definition of the output. The output is not defined as a scalar (one dimension), but as a vector with two dimensions i.e. a quantity (passengers or cargos) delivered at some location(s) within a time slot. The output is not related to some investment decision alone, but results from some market demand characteristics such as a mean rate of demand and a probability distribution of the locations of the demands. These market rate of demands, and demand locations may sometimes be more or less monitored through marketing actions. But controlled or not, they are one of the inputs of the system modifying the contribution of the other inputs.

To overcome the difficulty of dealing with a two dimension output, some authors (Kneafsey, 1975; Patton, 1970; Smith, 1973) have created some new units of measurement such as ton-mile or passenger-mile, but these new units of output are not above any reproach6. A transportation of 1000 passengers at 1000 miles is not equivalent to the transportation of 100 passengers at 10,000 miles. Trying to avoid dealing with the problem of two-dimension output, by creating an approximate single dimension unit, will not be the approach. Research has to keep the physical output with its multi dimension, since the cost of transportation is never in direct proportion to that of distance. The cost of transportation per unit of output will depend on the fleet size, the handling capacities, the probability distribution of the demand locations, and the probability distribution of departures and arrivals of any vector, element of the fleet.

PRODUCTION-SERVICE-DEMAND SYSTEM

A physical description of the system may be the following: it is made of vectors of transportation which have to perform a task, i.e. to transport in and out a certain number of passengers, and/or a certain number of tons of cargo, from an airport to some other airports within a certain time range. A mean rate of departures (or arrivals) must be reached, if one wants to meet the demand. The Production -Service system in systemic terms, embodies three sub-systems

     S1 is the production sub-system (the airport).
     S2 is the transportation sub-system (the airplanes).
     S3 is the demand (or task to be performed) sub-system.

Each subsystem is part of the system, but no one is self-sufficient. The airport runways or the airplanes are worthless without a mission to be accomplished. Time related demand will not be met without some vectors of transportation available to perform the mission in a timely fashion. Take-off for that demand will not immediately occur if all runways are busy. The output of the system is neither a built-in capacity of the production sub-system nor the transportation sub-system, nor a quantity, but it is a set of services to be performed within a time constraint. This set of services is indeed one of the inputs, parts of the production function.

For simplicity, an assumption is made that the production subsystem S1,j for a period j, is characterized by a set of Rj runways (fixed assets) with identical characteristics X1 (homogeneous airport), with a given rate of depreciation L1.

A similar assumption is made for the transportation sub-system S2,j; for a period j, the transportation sub-system is characterized by a set of Pj airplanes (fixed assets) with identical capacity X2 (homogeneous fleet), with a given rate of depreciation L2.

The demand sub-system is characterized by a set of Kj demands, for a period j in terms of flights to and from some specific locations Ak,j, (k being part of a set of Nj locations, Nj<Kj), within the period j).

Obviously, not a single sub-system (S1,S2 or S3) is a closed subsystem. It is a part of a Production-Service-Demand system at a given location, made of different fixed assets (runways and airplanes) owned by different owners (the airport Authority, and the Airlines) with the same individual goal, to make profit. This system is itself part of a larger system embodying all the other Nj airports (P-S-D systems themselves) interfering on the exploitation of the Production-Service-Demand system under scrutiny. The production Rj and transportation Pj fixed assets' population states may be adjusted for each period through acquisition or divestment of some components if resale is feasible (runways are not resalable!) to meet the changes in demand (with its time and spatial dimensions).

A decision d1,j may be made to build new runway(s) in order to meet the demand changes (or has to be made if the demand is growing and the runway's subsystem has reached a point of saturation) and/or to compensate for the runways having reached the limit of their economical life.

A decision d2,j may be made to buy new airplane(s) in order to meet the demand changes (or has to be made if the demand is growing and the fleet's subsystem has reached a point of saturation), and/or to compensate for the airplanes having reached the limit of their economical life.

State and decision variables are related differently accordingly to the age of the production and transportation subsystems.

$$Rj = Rj\text{-}I + d1,j \qquad\qquad for\ j < L1$$
$$Rj = Rj\text{-}1 + d1,j - d1,j\text{-}L1 \qquad for\ j > L1$$
$$Pj \ = Pj\text{-}1 \ + d2,j \qquad\qquad for\ j < L2$$
$$Pj = Pj\text{-}1 + d2,j - d2,j\text{-}L2 \qquad for\ j > L2$$

If one vector of transportation (airplane), one existing but not satisfied demand, and one servicing channel (runway) are simultaneously available, the total time to satisfy a demand will be equal to:

t1 + 2t2 + tn,3
with t2 the time required to travel one way from the airport of origin to the airport of destination,
t1 = 1 / X1 the time required to accommodate the take-off of a single plane at the airport of origin,(capacity of service X1)
and tn,3 = 1 / Xn,3 the time required to accommodate the landing of one airplane at location n (airport of destination), with a capacity Xn,..

To keep the model manageable and to retain an analytical approach, assumption is made that the system is working with a task predefined (with a backlog of demands) in such a fashion that the system cannot be idling for temporary lack of demands within the j-period.

P-S-D SYSTEM'S BEHAVIOR

From rational arguments, it is clear that the number of airplanes must be equal to or larger than the number of runways. A number of runways (servers) larger than the number of planes to be taken care of (serviced) would be a waste of resources. One or several servers would remain idle.

When the number of vectors of transportation (airplanes) is equal to the number of servers (runways) the larger system can be viewed as a juxtaposition of Nj identical systems, each vector of transportation being paired with a servicing unit. In that case, with a backlog of demands, the flow of vectors of transportation at the take-off location should not generate a traffic jam or queue. The transportation sub-system efficiency is equal to 1, from the origin airport standpoint (Its total efficiency will depend on the number of airplanes arriving at any given time at the destination airport, a number which could exceed the number of runways at that airport of destination!)

When the number of runways is less than the number of vectors of transportation the most usual case, a queuing pattern will develop. The transportation subsystem efficiency will decrease. Any addition to the transportation subsystem, even a single addition by one unit to a fleet size of one, will decrease the system efficiency. A traffic jam, a queuing problem has a likelihood to occur.

If one air carrier tries to meet the demand by increasing its fleet size, this enlargement will have two effects:

A fleet size increase will improve the coefficient of usage of the runway(s), if the airport is not already saturated.
Each fleet size increase will decrease the total efficiency of the transportation sub-system, and the efficiency of each airline.

At a given level of the fleet enlargement process, a point of saturation of the airport may be reached, a point where the usage ratio of the runways will be equal to 1. Beyond that point, any increase in the fleet size will be worthless. Any transportation vector added, after this saturation point, will stay idle at the airport. More than one vector will always be queuing for service. These vectors are indeed useless, and could be withdrawn from the system.

If the demand is indeed larger, capacity wise, than the capacity of the runways (servicing units), the demand will then be unmet. The solution will then be out of reach for the air carrier, as long as the airport authority does not enlarge its servicing capacity by building a new runway.

The Airport Authority may, - before having reach this runway's subsystem saturation point - help the air carrier(s) to meet the demand by increasing the number of runways available, a decision which will increase the efficiency of the transportation subsystem(s) by reducing the queuing time. Such a decision to invest into new runway(s) will be a decision to invest into one asset (runway) substitutable to some other asset(s) (vector(s) of transportation).

> *A runway population increase will decrease the coefficient of usage of the runway(s).*
> *Each runway population increase will increase the total efficiency of the transportation sub-system(s)*
> *Each fleet increase will decrease the fleet efficiency up to a point where any increase in the fleet size will be worthless. Any transportation vector added, after this saturation point, will stay idle at the airport. More than one vector will always be queuing for service. These vectors are indeed useless, and could be withdrawn from the system.*

In summary, each added unit of production has an diminishing output contribution up to a point of no contribution. One unit of production may be an envisage able substitution to some vector(s) of transportation. Also, each added vector of transportation has a diminishing output contribution up to a point of no contribution. This observation leads us to negate any economies of scale from the very beginning, when dealing with directly related production or transportation costs.

Considering the main characteristics of the return-of-scale concept explicited at the end of chapter II, it appears indeed that not a single of those described characteristics does apply. For example:

> *The market demand is real time related to the transportation sub-system, itself real-time related to the production sub-system. The market demand is equal to, but not larger than, the transportation subsystem output.*
> *The output is always defined as a two-dimension vector.*
> *The demand is one of the inputs*
> *The output of the transportation subsystem is related to the probability distribution of demand locations (airports of origin as well as airports of destination).*
> *The cost of delivery is not proportional to the distance (queuing time on the ground-take-off runway- or in the air - permission to land - is a cost component).*
> *The output of the transportation subsystem is related to the number of servicing channels (runways), at the hub as well as at all other destination airports.*

The output of the transportation subsystem attached to a production subsystem, is related to its own population as well as to all the other transportation subsystem's populations attached to the destination airports, and the destination airports' subsystems...

TASK PERFORMANCE COST

Costs attached to the task force P-S-D system are divided into variable costs, direct fixed costs and indirect fixed costs. The variable costs, in a classic theory approach, are by definition proportional to the output and constant for each unit of output. In a Production-Service-Demand system, this definition will have to be revised. The variable costs, directly linked to the servicing, transportation and landing steps (queuing steps excluded) required to accommodate one plane from its origin airport to its destination airport are indeed more or less constant for a given mean distance to the demand location. They will vary linearly with the distance (or the equivalent distance which will integrate some factors like the dominant wind).

The direct fixed costs are those fixed costs, B2 and B1, directly related to the ownership of a vector of transportation by the airline, and a unit of servicing by the airport authority. Those costs are represented by step-functions resulting from the discrete nature or the population. The indirect fixed costs are those overhead costs, A, which cannot be related to any specific vector of transportation and to any specific unit of servicing.

A third kind of cost, a variable cost which is not constant per unit of output, but not fixed, results from the queuing situation which develops itself, this queuing situation being a function of the system configuration and the probability distribution of arrivals and the probability distribution of departures. For an increase in demand, this variable cost per unit of demand will increase when the vectors of transportation's population will increase and will decrease when the servicing units' population will increase, and vice-versa. The net cost variation will depend indeed on the system's configuration. The transportation system total cost is equal to:

Variable costs Kj x H (t0 + (2dj / V) + t3) + Direct fixed cost B2 x Pj + B1 x Rj + indirect fixed cost A + variable cost (queuing)

with   dj the mean distance of the demand locations during period j
V the average velocity of the vector of transportation
H the variable cost per unit of time used to perform a delivery

The optimal configuration is the configuration with the minimum cost for a period or the configuration with the minimum net present value of those costs for a certain confidence time horizon.

P-S-D system's configuration cannot generally be optimized without simulation, the steady state being the exception and the demand being not analytically defined. However some simplified

P-S-D system, in a steady state, with mathematically defined probability distribution of servicing time, and transportation time are tractable with finite queuing tables.

CONCLUSION

In a production-transportation-demand system, it appears that the economies of scale concept such as the one defined in production systems is not applicable. Specifically:

> *Output is not scalar but a vector.*
> *Output cannot be defined without considering demand (a set of vectors) as one of the inputs.*
> *Any enlargement of the transportation subsystem's population is damaging the transportation system's efficiency (diminishing contribution).*
> *Any decrease of the mean value of the distance (one dimension of the output vector) from the server to the demand location is damaging the transportation subsystem efficiency.*

A range of unit cost decreases may be observed for some large amount of indirect fixed cost. However, one may not talk of economies of scale as defined by John Stuart Mill or Jacob Viner. From the study itself, one may draw some practical conclusion. If an airline is considering joining an existing transportation subsystem, to meet a growing demand with the same locations probability distribution, that airline is jeopardizing the entire system (increase of the airport congestion): the number of services performed by each vector within the same time period, if the demand is there, will decrease, and so the revenue per unit of transportation. However, this loss in revenue might be offset if the mean distance of the demand location increases or worsen if the mean distance of the demand location decreases. A good appreciation of the consequences of any change in the fleet size and the mean distance of the destination airports might prevent airlines in making poor decisions.

Several configurations with different proportion of units of service and units of transportation may meet the demand within a time limit. However, one may not expect from the airport authority any decision to increase the number of runways until those runways are fully saturated (airport congestion at the highest pitch!). Unless the airlines are transferring to the airport authority a fraction of the savings which may result from the airport investment decision. This day may never come. However the addition of a certain kind of fixed asset (a new runway or an extra airplane) at any period of the system's life may be the optimal decision.

An increase of the fleet size taking advantage of some runways' idle time but worsening the queuing situation may be the right step to minimize the cost of operating the system! An increase in the number of runways will decrease the queuing situation and improve the fleet efficiency, but the total operating cost of the system may become higher! For any owner of a transportation subsystem, the maximum profit goal rests upon the enlargement by the servicing subsystem's owner of its population. For any owner of a servicing subsystem, the maximum profit goal rests upon the status quo up to the point of saturation. Among all the feasible sets of combinations, only one is optimum at a given time horizon, for a given growth scenario. This optimal system configuration

does not belong to any subsystems' owner, but belongs to the system beneficiaries as a whole. If made in isolation, any investment decision may not be the correct decision. The system will not work at its best. Without system optimization, system survival is at stake. Without system survival, subsystem's survival is meaningless.

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THE APPLICATION DEVELOPER'S PERSPECTIVE ON JAVA CONNECTOR ARCHITECTURE

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ABSTRACT

This research tests the hypothesis that "Using the Java Connector Architecture, the application developers realize at least 25% cost-efficiency in building applications which connect new web-applications to the existing enterprise information systems". The integration of new applications with existing enterprise information systems (EIS) is problematic for most corporations throughout the world. EIS vendors have been providing proprietary interfaces as a solution to this problem, but until now no uniform standard architecture has existed. J2EE and its Java Community Process (JCP) partners offer a single and uniform standard, called the Java Connector Architecture (JCA), for integration solution. This study analyzes the main components of the JCA, reviews the abundant vendor support for the JCA and illustrates how applications developers within the IT department use this standard cost-efficiently. The focus of this paper is on the JCA from an application developer's perspective rather than from the vendor's point of view. This study critically evaluates how the JCA meets challenges, such as scalable, transactional, and secure access issues faced by application developers in enterprise application integration (EAI). A small survey is conducted which tests the hypothesis arriving at a conclusion that by using the JCA to link the heterogeneous enterprise information systems with application servers, a company is able to fully leverage its business value and protect its IT infrastructure investment cost-efficiently.

INTRODUCTION

For successful e-business operations, a company's IT department integrates its new web-based applications with the existing enterprise information systems (EIS) . Application developers throughout the world are facing challenges with integrating information and business processes within and between companies. EIS and other vendors provide their own proprietary interfaces with varying levels of support for integration solutions. Unfortunately, there is a lack of standard infrastructure for communicating with disparate systems. To solve this problem, Sun Microsystems and its Java Community Process (JCP) partners provide an industry standard called the J2EE platform. This platform includes numerous J2EE technologies, such as EJB, JMS, JSP, Java Servlet, the Java API for XML processing, RMI-IIOP and JDBC, which ease the difficulty of the EAI. Sun is continually improving its existing technologies while creating new ones. Sun's J2EE platform now includes a new standard for integration, namely the Java Connector Architecture (JCA), in providing connectivity between the J2EE compatible application servers and the existing

EIS. The JCA is viewed from both the vendor's and application developer's points of view. From the vendor's perspective, the JCA provides a set of standards concerning connection, transaction and security for building resource adapters, which connect e-business applications with various types of EIS. From the application developer's point of view, the IT department is required to have the knowledge to develop applications according to this standard for integration between the new web-applications and the existing EIS. The objective of this research is to evaluate the cost-efficiency of the JCA from the applications component developer's perspective.

RESEARCH METHOD: ITS IMPORTANCE AND SCOPE

Research Method: After analyzing JCA's main features and reviewing the reports on the support for its development and implementation given by the business community and different types of vendors, this research evaluates how the JCA meets the challenges faced by application developers in integration solution. A survey is conducted. From the results, this study empirically tests the hypothesis "Using the Java Connector Architecture the application developers realize at least 25% cost-efficiency in building applications that connect new web-applications to the existing enterprise information systems". The cost-efficiency is derived from two sources: 1) a fewer number of adapters, and 2) time saving in application development. As cost-efficiency from the fewer number of adapters is evident, this research tests the hypothesis on the basis of the time saving in application development. It also tests the cost-efficiency at different levels, such as at least 50%, 25% and 10%. In the hypothesis, at least 25% cost-efficiency is mentioned because it is considered as a reasonable amount for management to reallocate the application developer's time. This study compares the JCA with other technologies for integration. A conclusion is derived from these evaluations on the cost-efficiency of the JCA from the application developer's perspective.

Research Importance: Before the implementation of the JCA, x*y adapters are needed for integration if a company has x number of application servers and y number of EIS. The application developers must deal with x*y adapters. This process is complex and expensive. About 40% of programming efforts and 30% of IT investments (Leclerc, 2001) are used for this integration solution. This research points out how the application developers are able to build applications for the EAI easily and efficiently in an inexpensive way, and it also supports the managers' decision as to whether they can reallocate the IT resources, especially the application developer's time and effort. The scope of this research includes:

1 An Overview of the JCA
2 Vendor Support to the JCA
3 Evaluation of the JCA from an Application Developer's Perceptive
4 Empirical Evaluation of the JCA and Hypothesis Testing
5 The JCA in Comparison with Other Technologies
6 Limitations of This Research and the Future Research
7 Conclusion

AN OVERVIEW OF THE JCA

Java Connector Architecture (JCA) is a scalable, standard architecture for heterogeneous back-end enterprise information systems to "plug-and-play" with any J2EE compatible application servers (Sarathy, 2001). This connector architecture operates as part of the application server. To achieve its goal of integration solution, the architecture provides a simplified and uniform connectivity between the J2EE platform compatible application servers and the disparate EIS, which is implemented by EIS-specific resource adapters plugging into application servers.

The resource adapter is a system-level software driver that provides connectivity between the application server and the EIS. The resource adapter remains within the address space of the application server. The interface between the resource adapter and the EIS is specific to the EIS, and is a native interface. The Java Connector Architecture is diagrammatically represented in Figure 1 (Sharma, 2001, Pudichery, 2002).

Figure 1: JCA in J2EE Platform
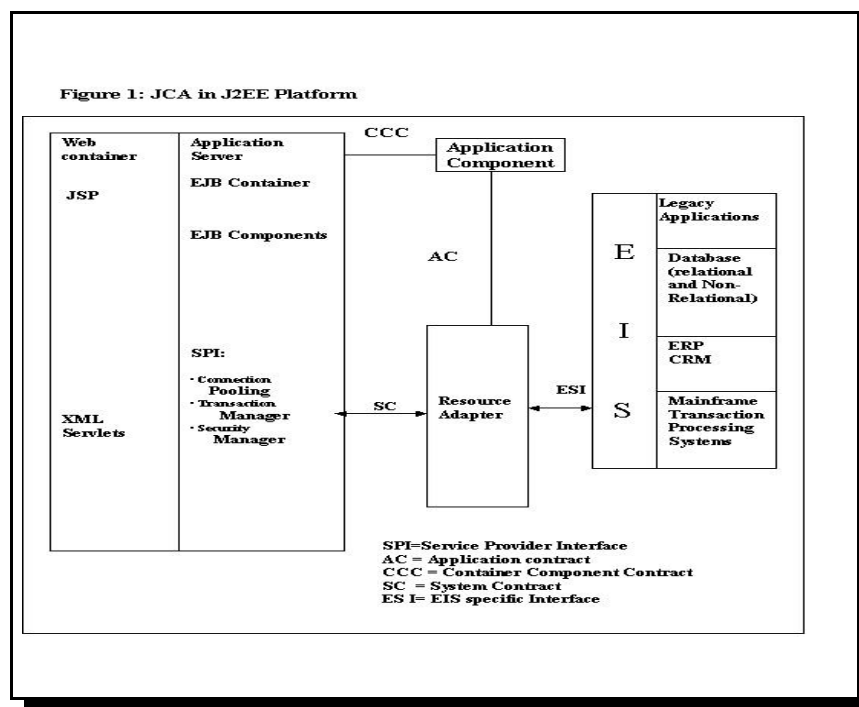
Java connector architecture has three components:1) System Contracts between application servers and resource adapters, 2) Common Client Interface, and 3) Packaging and Deployment Interfaces for resource adapters.

System Level Contracts between application servers and resource adapters play the role of Service Provider Interface (SPI). The SPI enables the container to gain connectivity to multiple EIS with different types of contracts: Connection Management, Transaction Management, Security Management, Transaction Inflow, Message Inflow, Life Cycle Management and Work Management

(Sun Microsystems, 2003). These contracts support inbound and outbound connectivity within the EIS enabling the resource adapter life cycle and thread management.

Common Client Interface (CCI) is a standard client API for application components. The CCI provides a mechanism for accessing heterogeneous systems, such as SAP R/3, Siebel, CICS and legacy applications, in a single and uniform way using the common client API. It is independent from a specific EIS. The resource adapter supports the CCI as a common client API for EIS connectivity. The integration tool vendors and EAI vendors do not have to adapt diverse EIS-specific client API for accessing diverse EIS.

Packaging and Deployment Interfaces provided by the JCA enable the various resource adapters to connect into the J2EE application servers. These include Java classes and interfaces developed by resource adapter providers.

VENDOR SUPPORT TO THE JCA

For successful implementation of the JCA, the vendors associated with integration solution need to support the JCA standard in their products. For example, EIS vendors ought to provide resource adapters; application server vendors should incorporate system level-contracts; EAI and integration tool vendors need to build JCA compliant connectors and define the CCI support for accessing heterogeneous EIS. A study conducted by Hansen and Mamorski (Hansen, 2001) reports that most of the EIS, application server and integration tool vendors, strongly support the JCA. EIS vendors, such as Siebel, JD Edwards, Lawson, PeopleSoft and SAP are providing the JCA adapters.

Many Application Server vendors incorporate the JCA standard in their products. For example, BEA Systems has adopted the JCA across the BEA Web Logic e-Business Platform. Borland Software Corporation has implemented this standard in Borland's AppServer 4.5 (Sun Microsystems, 2001). IBM, in its WebSphere, and HP Bluestone in its Total-e-Server, have actualized this standard. Application server vendors are able to leverage the strength of resource adapters to integrate the EIS without additional work.

Integration tool vendors, such as Attunity, Merant, Mercator, Sybase/NEON, TIBCO, Vitria, and WRQ, who now have proprietary standards within their integration servers, support the JCA because it increases the value of their products.

Moreover, Sun is maintaining support and commitment from several corporations through the Java Community Process (JCP). The JCP participates in developing and revising Java technology specifications.

EVALUATION OF THE JCA FROM THE APPLICATION
DEVELOPER'S PERSPECTIVE

The application developer's perspective focuses on how the JCA solves challenges facing the application developers in integrating the J2EE compatible-standard enterprise applications with

the existing IT infrastructure. One main challenge is discovering how the JCA enables the application developers to build applications which will provide a scalable, transactional and secure access of web applications to the EIS easily and cost-efficiently (Sharma, Stearns and Ng, 2001).

Scalable Access: One important job of the application component developer is to make the web applications scalable. A large number of clients and web applications in e-business have to access the EIS and legacy applications. They are not able to access the existing EIS concurrently due to the limited number of expensive connection resources. The existing connections are allocated to the incoming web-applications in a scalable way, which is achieved through connection pooling. The JCA supports connection pooling, but it does not define any specific mechanism for pooling. The new web-applications receive connections to the EIS using a set of standard programming model. The application component developer in the IT department needs to know the common client interface (CCI) of the standard programming model to provide applications, the required scalability and to reuse the existing connections.

Transactional Access: In the integration process, every application performs a certain type of transactional operation with the EIS data. Moreover, there are a multitude of users accessing the same EIS, which have different transactional characteristics requiring multiple resource managers. In these circumstances, possibilities exist for an application to end up with the wrong data or the EIS data may be corrupt. The application developer's job is to ensure the integrity of data through the enforcement of ACID (Atomicity, Consistency, Isolation and Durability) properties of transactional operation while integrating with the EIS. The implementation of the ACID properties guarantees that all operations are performed successfully keeping the EIS in a consistent state when the operations are complete, that this data is manipulated in isolation by each single transaction, and that the updates completed through transactional operations are durable. Guaranteeing the ACID properties of transaction is costly if the application developers use complex programming models. The Java Connector Architecture together with other J2EE technologies facilitates the application developer's work by providing a transaction management contract which enables him/her to use a standard J2EE programming model without worrying about the transaction management complexities when an application is trying to gain transactional access to EIS data.

Secure Access: Another job of the application component developer is to provide a secure access to the EIS for the web applications. Any unauthorized access to the EIS may destroy or corrupt the EIS data that is expensive to the enterprise. The security measures include authentication and authorization and access control to the EIS. Authentication identifies the user. Authorization and control access decide whether the user has the privilege to access the specific EIS. Generally, the application developers allocate time to enforce these measures for a web application's access to the EIS. These security measures are provided by the security management contract of the JCA. The only thing that an application developer has to do is to specify declaratively these measures for application in the deployment descriptor. This security goal is achieved through the EIS sign-on mechanism. The security management contract of the JCA saves much time for the application developers.

Easy to use: Until the JCA is implemented, if a corporation desires to integrate its J2EE application servers with diverse EIS, it may have to use proprietary systems provided by EIS vendors (Radding, 2001). If a company decides to use EIS proprietary tools, separate bridges are required for each application server and for each enterprise information system. It is an expensive and time-consuming venture. The JCA connectors solve this problem in a single, uniform interface, called CCI, and the "plug-and-play" method of resource adapters. Each EIS vendor provides only one standard resource adapter per type of the EIS (Cattel, 2001), which can be plugged into application servers. A company may then buy off-the-shelf JCA connectors, if available, or it may write its own adapter. Thus the JCA provides an interoperability standard, which makes the enterprise application integration (EAI) much easier now than ever before.

Cost-Efficiency: Cost efficiency is derived from two sources: 1) fewer number of adapters and 2) less time needed for application development.

Fewer Number of Adapters: The connector architecture supports application integration at minimal overhead and maintenance support. Enterprises have been using proprietary EIS tools for the integration of web applications with the EIS. If a company has x number of application servers and y number of EIS, it needs x * y separate bridges for the integration. This procedure is costly and expensive, but by using the JCA, the company needs only x + y resource adapters. The result is a substantial cost reduction.

Less Time for Application Development: The JCA enables the application developers to save a tremendous amount of time in providing scalable, transactional and secure access of web applications to the EIS. A resource adapter, plugging into an application server, implements the system-level contracts, and thereby, it can easily achieve a scalable, transactional, and secure integration between the application server and the EIS in a way specific for the given EIS. The application developers using the standard programming model save time in application development. They can focus on the development of business and presentation logic of application components without fretting over system-level issues.

EMPIRICAL EVALUATION OF SURVEY RESULTS AND HYPOTHESIS TESTING

Empirical Evaluation: Data for this research was collected through questionnaires sent to the IT departments of Fortune 500 companies. One hundred IT professionals representing different companies were contacted and asked to complete the questionnaire regarding the strengths and weaknesses of the JCA.

Twenty-four (24%) responses were received. Three companies do not use the JCA; therefore, only twenty-one responses are included in this evaluation. These participants represent twenty-one different companies and use different types of application servers, such as BEA WebLogic, IBM WebSphere, Sun iPlanet, and Jboss.

Twenty participants responded that the JCA saves time in building applications that connect the new web applications to the EIS. There is a difference of opinion on how much time is saved

in linking web applications to the EIS data compared to the previous system they had been using. Table 1 shows the percentage of time saving in relation to their previous system and the number of responses.

Table 1
Percentage of Time Saving thru the use of the JCA

Cost/efficiency (%)	# of Responses
50% or more	4
25% - 49%	10
10% - 24%	6
Less than 10%	1

The above responses are subdivided according to the company size . The survey participants were asked to select their company size among the Fortune 500 companies. They were given three choices: large, medium and small. Table 2 illustrates the company size and the number of responses at different levels (percentages) of time saving in application development .

Table 2
Company size and Number of responses at different levels of cost/efficiency

Company Size	50% or more	25%-49%	10%-24%	Less than 10%
Large	3	1	0	0
Medium	1	4	1	1
Small	0	5	5	0

One correlation addressed in Table 2 reveals that larger companies reflect a higher percentage of saving time for the application developer in building the applications.

Hypothesis Testing: Assuming that if p>0.5, the hypothesis is accepted, a binomial test is conducted. The two groups, such as "50% or more" and "25% - 49%" cost reductions, are combined into one, which determines the probability of success; and the other two groups, such as "10%-24%" and "less than 10%", are combined into another which determines the probability of failure. The binomial test resulted in accepting the hypothesis at a 95% confidence level. Similarly, the hypothesis is tested with changing the values of the cost-efficiency into "at least 50%" and also "at least 10 %". At "50% or more" cost-efficiency level, the hypothesis is rejected, and at "10% or more" cost-efficiency, it is accepted at a 100% confidence level. Bear in mind that the sample size is small.

THE JCA IN COMPARISON WITH OTHER TECHNOLOGIES

A comparison of the JCA and Microsoft.Net technologies: Microsoft.NET platform have integration technologies, such as the Host Integration Server ,COM TI and MSMQ; however, these technologies are used only for certain specific integration solutions.

In this empirical study, twenty participants (98%) responded that the JCA is superior to the Microsoft.NET platform technologies for EIS integration and that Microsoft does not currently possess any product of the same caliber as the JCA.

A comparison of the JCA with other J2EE technologies: For integration solution, Sun Microsystems has other technologies, such as EJB, JDBC, JMS, and Java-XML. The legacy codes in the EIS are wrapped into EJB components and then are connected to the application servers (Fisher, 2001). Wrapping legacy codes into EJB components is expensive and requires skills in advanced Java programming. The message beans of the EJB are used for asynchronous messaging mechanism between applications. They can not be used for synchronous messaging. Another technology is the use of JDBC; however, JDBC API is used only for relational database integration. Similarly, SUN has a powerful JMS message queuing for integrating enterprise systems; however, if the data is not relational and the enterprise systems are not capable of message queuing, a company must turn to the JCA, which allows enterprise systems to be accessed through their native API. Another technology is the Java-XML. Back-end EIS applications are converted into XML documents which are linked to application servers; similarly, EJB components are given the XML format and are transferred across the enterprise. The new version of the JCA has the capability of converting the EIS into XML format, and of transferring it across the enterprise. The JCA complements other J2EE technologies (Stolker, 2001).

When the JCA is compared with other J2EE technologies in the order of preference, 40% of the respondents gave Java-XML first preference, 35% of the respondents gave the JCA the second preference, and 25% of the respondents gave EJB the third preference. All respondents agree that the JCA complements the J2EE other technologies in integration solution.

LIMITATIONS OF THIS RESEARCH AND THE FUTURE RESEARCH

The JCA is comparatively a new J2EE technology for enterprise application integration. The first version of the JCA had many limitations. Numerous companies delayed implementing the JCA until a new version was created. When the questionnaires for this study were sent out, there was scarcity of data on this topic resulting in the small sample size of twenty-one. With a minute sample size of twenty-one, it is virtually impossible to adequately determine whether the hypothesis is accepted or rejected. As it is an important issue in application development for the EAI, further studies with a larger sample size are needed in the future. Another area of future research is to determine the correlation between the size of the company and time savings in application development and its significance level. By that time, there will probably be more technologies for

the EAI. Comparative studies of the technologies for the EAI will also be beneficial for successful businesses.

CONCLUSION

The JCA is an interoperability standard for the enterprise integration solution. It is implemented through the plugging of resource adapters into the J2EETM platform compatible application servers. It meets the challenges, such as scalable, transactional, and secure access issues, faced by application developers in integration solution. This research tests the hypothesis that "Using the Java Connector Architecture the application developers realize at least 25% cost-efficiency in building applications that connect new web-applications to the existing enterprise information systems". Empirically, we accept the hypothesis at a 95% confidence level; but it should be noted that the sample size in this study is small. Comparatively, the JCA is currently superior to Microsoft.NET technologies, and it complements the other J2EE technologies. The Java Connector Architecture is a single and uniform standard for the integration of web-based new applications with back-end EIS. By using this standard to link the heterogeneous enterprise information systems with application servers, a company can fully leverage its business value and protect the IT infrastructure investments cost-efficiently.

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APPENDIX A
Questionnaire on Java Connector Architecture

1. What type of company do you represent?	○ Government ○ Financial ○ Research ○ Manufacturing ○ Transportation ○ Computer ○ Communication Other: [____]
2. Is enterprise application integration (EAI) critical to the function of your company?	○ Yes ○ No
3. Are you using Multitier Client/Server Systems?	○ Yes ○ No
4. Which platform are you using for your business (e-business) transactions?	☐ J2EE platform ☐ Microsoft.Net Other: [____]
5. What is the size of your company among the Fortune 500 companies?	☐ Large ☐ Medium ☐ Small
6. Which Application Servers are you using?	☐ WebLogic ☐ WebSphere ☐ Total-e-Server ☐ GemStone/J ☐ Microsoft Product Other (please specify) [____]
7.Your application server supports the J2EE platform:	○ Fully ○ Partially ○ not at all
8. What are the main problems you face in Enterprise Application Integration (EAI)?	☐ Connecting heterogeneous clients and servers ☐ Connecting heterogeneous back-end systems ☐ Connecting legacy applications not written in Java ☐ Connecting non-relational database ☐ Connecting mainframe transaction systems ☐ Building applications quickly and efficiently Other (please specify) [____]

9. What are the main J2EE Technologies you use for Enterprise application integration (EAI) solution?	☐ Java Servlet ☐ RMI-IIOP ☐ JMS ☐ JTA ☐ JTS ☐ Java IDL/CORBA ☐ JDBC JNDI ☐ Java Mail ☐ Java-XML ☐ Java Connector Architecture (JCA)
10. Please specify and prioritize three J2EE technologies that are the most useful for the EAI solution:	☐ EJB ☐ Java Servlet ☐ JSP ☐ RMI-IIOP ☐ JMS ☐ JTA ☐ JTS ☐ Java IDL/CORBA ☐ JDBC JNDI ☐ Java Mail ☐ Java-XML ☐ Java Connector Architecture (JCA)
11. Back-End EIS applications in your company consist of:	☐ Legacy System written in Java ☐ Legacy System written other than Java ☐ Relational Database ☐ Non-Relational Database ☐ ERP ☐ CRM ☐ Mainframe Applications Other (please specify)
12. Technologies you use for integrating Web Application with Back-End EIS Applications:	☐ Integration Brokers ☐ JDBC ☐ Wrapped in EJB ☐ Converting into XML documents ☐ Java Connector Architecture ☐ Vendor Proprietary Interfaces ☐ IBM's External Call Interface Other (please specify)
13. How do you rate the Java Connector Architecture (JCA) for enterprise application integration compared to Microsoft.NET Tools?	☐ Superior to Microsoft.NET Tools ☐ Inferior to Microsoft.NET Tools ☐ At the same level.

14. In your opinion, some limitations of the Java Connector Architecture are:	☐ Lack of bi-directional communication ☐ Lack of support for asynchronous transaction ☐ Lack of support for metadata ☐ Lack of built-in support for XML Other (please specify)
15. In using the JCA, what percentage of time do you save in building applications to provide connections between the new web-applications and the existing enterprise applications (EIS),	☐ 50% or more ☐ between 25% - 49% ☐ between 10% - 24% ☐ Less than 10% Other (please specify)
16. Do you think the JCA is superior to Microsoft.NET platform technologies for the EAI?	○ Yes ○ No

AN ANALYSIS OF DIFFERENCE SCORE MEASURES OF LATENT BUSINESS CONSTRUCTS

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ABSTRACT

This study empirically investigates the reliability and construct validity of difference score measures of latent business constructs in comparison to that of non-difference score measures of latent business constructs. Results provided evidence that question the conventional wisdom that the use of difference scores should be avoided whenever possible. Also, the thorough empirical examination of reliability and construct validity provides a framework for practitioners who wish to properly evaluate different measurement techniques.

INTRODUCTION

Difference scores are created when one measure is subtracted from another to create a measure of distinct construct (Peter, Churchill & Brown, 1993). Several researchers (Peter, Churchill & Brown, 1993; Johns, 1981; Cronbach & Furby, 1970; Nunally, 1959; and Mosier, 1951) have cited potential problems with difference scores, such as problems with reliability, discriminant validity, spurious correlation and variance restriction, which can cause them to perform poorly as measures of latent constructs. There is clearly a need for empirical study of the possible problems encountered when using difference scores to measure latent business constructs. This paper assesses the reliability and validity of difference score measures of latent business constructs in comparison to the reliability and validity of non-difference score alternatives purported to measure the same latent business constructs.

Difference Scores

A significant portion of the literature on difference score measures is in the area of testing and measurement (Cronbach & Furby 1970; Lord, 1958; and Mosier, 1951). In the business area, difference scores have been used mostly in behavior-oriented fields and are generally concerned with the measurement of latent constructs, although there has been application in economics and finance (Ogden, 1990).

The most common methods of expressing difference scores are simple absolute differences, differences between profiles and signed (algebraic) differences (Johns, 1981). Simple absolute differences are considered "simple" in that their components consist of single-item scores or summary scores derived from a scale of items (Johns, 1981). The term absolute implies that the direction of the difference is not important, only the magnitude.

Profiles are graphic summaries of multiple-item measures which retain the identity of each item until all are combined into a summary difference measure (Mosier, 1951). Use of profile differences requires the assumption that the direction of the difference is not important. However, unlike simple absolute differences, profiles have components that consist of more than a single variable (Johns, 1981).

Johns (1981) related that differences between profiles are commonly expressed as:

1   Sum of the absolute differences between parallel profile points to obtain an index of dissimilarity (Bernardin & Alvares, 1975; Green & Organ, 1973).
2   Sum of the squares of the absolute differences between parallel profile points to obtain the index of profile dissimilarity or D2 (Cronbach & Gleser, 1953).
3   Square root of the D2 index (Frank & Hackman, 1975; Senger, 1971). Algebraic, or signed, differences are formed when the direction of the difference is maintained, allowing researchers to consider both magnitude and direction of differences.

While researchers often employ various weighting strategies in the calculation of difference scores, these are primarily study-specific and will not be addressed in this paper. However, the method used to combine component parts into difference score measures must be considered carefully prior to any statistical analysis employed using difference scores as inputs.
Peter, Churchill and Brown (1993) describe four areas in which problems may occur with the use of difference scores. These include:

Reliability - Problems with reliability of difference scores are primarily focused in:

1   The inherently low reliability of difference scores. Difference score reliability is usually lower than the reliabilities of their component variables (Peter, Churchill, & Brown, 1993; Prakash & Lounsbury, 1983; Johns, 1981; and Mosier, 1951).
2   The failure of researchers to report reliabilities of difference scores; the failure to correctly calculate the reliability of difference scores. In their analysis of difference score applications used in consumer research, Peter, Churchill and Brown (1993) found that only four of 13 studies attempted to assess reliability scores. All four (of those assessing reliability) assessed reliability incorrectly.
3   The effect of intercomponent correlation. The reliability of a difference score will equal the average of the reliabilities of its components only when the intercomponent correlation is zero.

Discriminant Validity - Discriminant validity is impacted from two sources:

1 Reliability effects. For various reasons, difference scores often have low reliability. It is possible that the correlations between a difference score measure and other measures may give the impression that discriminant validity standards are met simply because of low reliability.

2 Combination effects. Measures formed as linear combinations of scale scores (as with difference scores) may have difference scores that cannot be distinguished from its components, thereby failing to demonstrate discriminant validity.

Spurious Correlation - An additional problem is the tendency of difference scores to be correlated with other measures. This is primarily due to the tendency of difference scores to be correlated with their component parts (Peter, Churchill & Brown, 1993). In addition, spurious correlation is hard to separate from legitimate correlation.

Variance Restriction - Restriction of the variance of a difference score measure may occur when one of the components used to calculate the difference score is consistently higher than the other (Peter, Churchill & Brown, 1993).

Alternatives to Difference Scores

Given the potential problems associated with the use of difference scores to measure latent constructs, several alternatives have been suggested by researchers (Peter, Churchill & Brown, 1993; Cronbach & Furby, 1970). Suggestions include:

1 Designing single statement measures that require the respondent to subjectively compare the two constructs whose measures were used to create the difference score measure of the latent construct (subjective difference method);

2 Reframing research questions to avoid any comparison of the constructs whose measures were used to create the difference score measure of the latent construct (single statement method), and

3 Using a multiple regression approach to determine the appropriate weight to assign to the measures of the constructs used to create the difference score measure of the latent construct, rather than "forcing" the measures into a predetermined form as is the case with the construction of difference score measures of latent constructs.

RESEARCH HYPOTHESES

To thoroughly assess the reliability and validity of difference scores, it was necessary to compare difference score and non-difference score measures of the same latent business constructs in a single study. Two latent business constructs, net perceived return and disconfirmation of expectations, were selected from the business literature because they could be used to develop a single research instrument focused around a common theme. Specifically, the net perceived return and disconfirmation of expectations associated with the hypothetical purchase of a small 4-door economy car were measured by a difference score method and two non-difference score alternative methods.

Research hypotheses are offered to facilitate the empirical analysis of difference score measures of latent business constructs. The following hypothesis is offered to provide a framework for the detailed empirical investigation of the reliability of difference score measures and their alternatives.

> *H1: There is no difference in the reliability of difference score and non-difference score measures*
> *of latent business constructs.*

In addition to the need for a thorough examination of the reliability of a measure, researchers should investigate a measure's nomological, convergent and discriminant validity of difference score measures and their alternatives (Peter, 1981). Hence:

> *H2: There is no difference in the nomological validity of difference score and non-difference score*
> *measures of latent business constructs*

> *H3: There is no difference in the convergent validity of difference score and non-difference score*
> *measures of latent business constructs*

> *H4: There is no difference in the discriminant validity of difference score and non-difference score*
> *measures of latent business constructs.*

The evaluation of a measure's nomological validity requires an empirical analysis of the measure of the construct of interest and measures of other constructs theoretically linked to the construct of interest (Peter, 1981). Therefore, the nomological validity of the difference score measures and their alternatives were investigated by examining their relationships with measures of other theoretically related constructs.

The research instrument (Appendix A) included items measuring the respondent's overall impression and expected resale value of the 4-door economy used in the study. Overall impression and expected resale should be significantly correlated with the net perceived return and disconfirmation associated with the hypothetical purchase of the small 4-door economy car. Investigation of the relationship of the measures of the net perceived return and disconfirmation of expectations with variables measuring the overall impression and expected resale value of the 4-door economy car requires the introduction of four secondary hypotheses (Hypotheses 2a-2d). Utilization of hypotheses 2a through 2d ensured that the nomological validity of difference score and non-difference score measures were compared in a consistent manner; that is, Hypotheses 2a through 2d are proposed to provide the framework necessary to investigate Hypothesis 2 in a consistent manner.

> *H2a: Difference score measures of net perceived return and non-difference score measures of net*
> *perceived return are not different with respect to their correlation with the overall impression of 4-*
> *door economy car x.*

H2b: Difference score measures of disconfirmation of expectations and non-difference score measures of disconfirmation of expectations are not different with respect to their correlation with the overall impression of 4-door economy car x.

H2c: Difference score measures of net perceived return and non-difference score measures of net perceived return are not different with respect to their correlation with the expected resale vale of 4-door economy car x.

H2d: Difference score measures of disconfirmation of expectations and non-difference score measures of disconfirmation of expectations are not different with respect to their correlation with the expected resale value of 4-door economy car x.

RESEARCH METHOD

To investigate the research hypotheses it was first necessary to determine an appropriate research methodology. Multitrait-multimethod analysis was selected as the primary method of validity assessment due to its support in the psychometric literature. The decision to use multitrait-multimethod analysis necessitated the research design employed in this study.

Multitrait-multimethod analysis requires that two or more traits, or constructs, be measured by two or more methods with a single research instrument. The two latent business constructs, net perceived return and disconfirmation of expectations meet the conditions required for multitrait-multimethod validity analysis.

Each latent trait, or construct, was measured by three methods: one difference score method and two non-difference score alternative methods. The first non-difference score alternative, the "subjective difference method," required respondents to subjectively compare the two constructs whose measures were used to create the difference score measure of the latent construct. The second non-difference score alternative, the "single statement method," employed research questions that avoided any comparison of the two constructs used to create the difference score measure of the latent construct. A detailed discussion of the latent business constructs examined in the study, along with the scales used to operationalize the constructs, follows.

Net Perceived Return

The net perceived return construct was introduced by Peter and Tarpey (1975) as an alternative theoretical formulation of how consumers evaluate the risks and returns associated with purchase decisions. They (Peter & Tarpey, 1975) stated that, in the context of risk-return typology, there would appear to be three distinct strategies in terms of how consumers make decisions:

Select the brand that minimizes expected loss (perceived risk),
Select the brand that maximizes expected gain (perceived return), and
Select the brand that maximizes net expected gain (net perceived return).

Peter and Tarpey (1975) investigated each alternative and concluded that the net perceived return alternative explained more variance in automobile brand preference than the other two.

Difference Score Method. Using Lewin's (1943) vector hypothesis of consumer behavior as a theoretical basis, net perceived return can be defined as the difference between overall perceived return and overall perceived risk as shown (Peter & Tarpey, 1975: 30):

$NPRe_j = f(OPRe_j - OPR_j) = f \sum [(PG_i \cdot IG_{ij}) - (PL_{ij} \cdot IL_{ij})]$

where:

$NPRe_j$	=	net perceived return for brand j
$OPRe_j$	=	overall perceived return for brand j
OPR_j	=	overall perceived risk for brand j
PG_i	=	probability of gain i from purchase of brand j
Ig_{ij}	=	importance of gain i from purchase of brand j
PL_{ij}	=	probability of loss i from purchase of brand j
IL_{ij}	=	importance of loss i from purchase of brand j
n	=	utility facets

Six utility facets were used in the Peter and Tarpey (1975) study. These same six are incorporated into this study and include: financial risk-return, performance risk-return, psychological risk-return, physical risk-return, social risk-return, and time risk-return. The net perceived return scale developed by Peter and Tarpey (1975) appears in Appendix A.

Subjective Difference Method. The subjective difference method of recasting a difference score into a single statement was used in the context of net perceived return to ensure that the measurement methods were consistent for the disconfirmation of expectations and net perceived return constructs. Statements were developed that required the respondents to subjectively compare the potential loss and gain associated with the hypothetical purchase of a small 4-door economy along each of the six utility facets. These statements are referred to as "subjective loss-gain comparisons" (SLG_{ij}). Since the difference score measurement model of the net perceived return construct ($NPRe_j$) employs utility facet importance weights, it was necessary to create a utility facet weighting scheme for the subjective net perceived return ($SNPRe_j$) model. The importance of a gain (Ig_{ij}) and the importance of a loss (IL_{ij}) were averaged to provide a weighting factor (I_{ij}) for each utility facet. The subjective difference model used to measure the net perceived return ($SNPRe_j$) is:

$SNPRe_j = f \sum (I_{ij} \cdot SLG_{ij})$

where:

$SNPRe_j$	=	net perceived return for brand j (subjective measure)
SLG_{ij}	=	subjective loss-gain comparison I from purchase of brand j
Iij	=	$(IG_{ij} + IL_{ij}) / 2$, importance of utility facet I
Ig_{ij}	=	importance of gain I from purchase of brand j
IL_{ij}	=	importance of loss I from purchase of brand j
n	=	utility facets

The scale used to measure the subjective loss-gain comparisons (SLG$_{ij}$) necessary to construct the subjective difference measure of the net perceived return construct is shown in Appendix A.

Single Statement Method. Consistent with the research of Peter and Tarpey (1975), overall perceived risk (OPR$_j$) was used as a non-difference score alternative formulation of how consumers evaluate risks and returns associated with the hypothetical purchase of a small 4-door economy car. Of interest is the fact that Peter and Tarpey (1975) found that overall perceived risk (OPR$_j$) explained more variation in brand preference than net perceived return for one of the automobiles evaluated in their study.

Disconfirmation of Expectations

The disconfirmation of expectations construct has been widely used in the study of consumer satisfaction (Prakash & Lounsbury, 1983) and occupies a central position as a crucial intervening variable (Churchill & Surprenant, 1982). Since disconfirmation arises from discrepancies between prior expectations and actual performance, it is presumably the magnitude of the disconfirmation effect that generates satisfaction and dissatisfaction (Churchill & Surprenant, 1982). According to Oliver and Swan (1989), satisfaction is a result of these steps: "Prior to an exchange, consumers hold attribute norms or form attribute performance expectations. As the product is used or service rendered, the consumer compares performance perceptions to these prior comparison standards. Performance above the standard has been termed positive disconfirmation, while performance below is referred to as negative disconfirmation. The degree of incremental (dis)satisfaction is a direct function of positive (negative) disconfirmation."

Historically, researchers have used both difference score and non-difference score alternative measures to operationalize disconfirmation of expectations (Tse & Wilton, 1988; Prakesh & Lounsbury, 1983; and Oliver, 1980). These include the difference score method, subjective difference method and the single statement method and each is discussed with regard to disconfirmation of expectations.

Difference Score Method. The difference score measurement model used to measure the disconfirmation of expectations associated with the hypothetical purchase of a small 4-door economy car is:

$DISC_j = EXP_j - PER_j = \Sigma E_{ij} - \Sigma P_{ij}$
where:
$DISC_j$ =   disconfirmation of expectations for brand j
EXP_j =   overall expectation of brand j
PER_j =   overall perception of brand j
E_{ij} =   expectation of facet i of brand j
P_{ij} =   perception of facet i and brand j
n =   utility facets

The expectations and perceptions components needed to create a difference score measure consistent with Peter and Tarpey's (1975) net perceived return were developed and are shown in Appendix A. This scale is consistent with those employed by others who have used difference scores to measure disconfirmation of expectations (Tse & Wilton, 1988; La Tour & Peat, 1979).

Subjective Difference Method. The subjective difference method for measuring disconfirmation of expectations requires that the respondent record a summary judgment on a "better than expected - worse than expected" scale. The subjective difference model is:

$SDISC_j = \sum Sd_{ij}$
where:
$SDISC_j$ = disconfirmation of expectations for brand j (subjective measure)
SD_{ij} = subjective disconfirmation of expectations of utility facet i for brand j

Oliver's (1980) three item, subjective disconfirmation approach measuring customers' subjective disconfirmation with an automobile dealer's service department was used as basis for the development of a scale consistent with the six utility facet dimensions used in Peter and Tarpey's (1975) net perceived return model. This scale, measuring disconfirmation in the context of the hypothetical purchase of a small 4-door economy car, is shown in Appendix A.

Single Statement Method. Overall perception (PER_j) was used as an additional measure of the disconfirmation of expectations construct. While overall perception is not a measure of disconfirmation, it is necessary to treat it as such in order to have the same three methods measuring all latent traits included in the research instrument. Otherwise, it is not possible to perform multitrait-multimethod validity analyses.

Sample

The sampling frame consisted of undergraduate students enrolled in business classes at a small Midwestern college. Three hundred ten questionnaires (Appendix A) were completed.

RESULTS

The evaluation of the research hypotheses is presented in two parts. First we present the results and analysis of the hypothesis concerning the reliability and difference scores. In the second part, we present the results and analyses of evaluating the validity hypotheses.

Reliability Assessment

Coefficient Alpha Reliabilities. The reliabilities of all non-difference score measures and the components necessary to construct the difference score measures of the latent business

constructs were first assessed using coefficient alpha (Cronbach, 1951). The alphas calculated for the components necessary to construct the difference score measures of the latent business constructs along with their variances and intercomponent correlations were then used to determine the reliability of the difference score measures of the latent business constructs measured in the study. The resulting alphas ranged from .72 to .83. Tables presenting all pertinent information are available upon request from the authors. Available tables are listed in Appendix B.

Difference Score Reliability Assessment. Table 1 contains the reliabilities, variances and intercomponent correlations used to calculate the reliability of the difference score measure of the disconfirmation of expectations construct along with the difference score reliability calculated for this measure. Table 2 presents the same information for the net perceived return construct.

A summary of the reliabilities of the three methods used to measure the disconfirmation of expectations construct are shown in Table 3. A summary of the same reliability information for the net perceived return construct is presented in Table 4.

Table 1
Input Necessary to Calculate Reliability of Difference Score Measure of
Disconfirmation of Expectations Construct

Component	Reliability	Variance
Expectations	0.79	45.04
Perceptions	0.81	42.29
Intercomponent Correlation = 0.58		
Difference Score Reliability = 0.52		

Table 2
Inputs Necessary to Calculate Reliability of Difference Score Measure of Net Perceived Return Construct

Component	Reliability	Variance
Overall Perceived Return	0.80	2474.82
Overall Perceived Risk	0.77	1969.33
Intercomponent Correlation = -0.07		
Difference Score Reliability = 0.80		

Table 3
Summary of Reliabilities for the Three Methods Used to Measure the
Disconfirmation of Expectations Construct

Method	Reliability
Difference Score Method	0.52
Subjective Difference Method	0.72
Single Statement Method	0.81

Table 4
Summary of Reliabilities for the Three Methods Used to Measure the Net Perceived Return Construct

Method	Reliability
Difference Score Method	0.80
Subjective Difference Method	0.83
Single Statement Method	0.77

Reliability Hypothesis Tests. Hypothesis 1 was evaluated using the methodology proposed by Feldt, Woodruff and Salih (1987) to test the hypothesis of equality of coefficients alpha (Ho = A1 = A2) when the alpha estimates are based on the sample. Note that the difference score reliabilities are not coefficient alpha reliabilities, but were treated as such in order to employ the method proposed by Feldt, Woodruff and Salih (1987).

The difference score reliabilities were compared in a pairwise fashion with the reliabilities of each of the two non-difference score alternative measures for each latent business construct. The following test statistic was used (Feldt, Woodruff & Salih, 1987: 99):

$$t = \frac{(\alpha_1 - \alpha_2)(N-2)^{1/2}}{[4(1-\alpha_1)(1-\alpha_2)(1-p^2)]^{1/2}} \quad \text{(Degrees of Freedom} - N-2)$$

where N = sample size, α_1 and α_2 are sample coefficients alpha, and p is the correlation between the two summative measures developed from the sample data.

Table 5 contains a summary of the hypothesis tests of reliability difference for the disconfirmation of expectations construct. Table 6 presents the same information for the net perceived return construct.

Table 5
Hypothesis Test of Reliability Difference For Disconfirmation of Expectations Construct

Difference Score (#1) vs. Subjective Difference		Difference Score vs. Single Statement (#3)	
H_0: $A_1 = A_2$		H_0: $A_1 = A_3$	
H_1: $A_1 \neq A_2$		H_1: $A_1 \neq A_3$	
Inputs for t calculation:	$\alpha_1 = 0.52$	Inputs for t calculation:	$\alpha_1 = 0.52$
	$\alpha_2 = 0.72$		$\alpha_2 = 0.81$
	$\rho = -0.16$		$\rho = 0.43$
	$N = 310$		$N = 310$
Results:	$t = -4.85$	Results:	$t = -9.36$
	DOF = 308		DOF = 308
	p-value = 0.000		p-value = 0.000

Note: Numbers have been rounded to 2 places for illustrative purposes. Greater than 2 place accuracy was used in all calculations.

Table 6
Hypothesis Test of Reliability Difference For Net Perceived Return Construct

Difference Score (#1) vs. Subjective Difference		Difference Score vs. Single Statement (#3)	
H_0: $A_1 = A_2$		H_0: $A_1 = A_3$	
H_1: $A_1 \neq A_2$		H_1: $A_1 \neq A_3$	
Inputs for *t* calculation:	$\alpha_1 = 0.80$	Inputs for *t* calculation	$\alpha_1 = 0.80$
	$\alpha_2 = 0.83$		$\alpha_2 = 0.77$
	$\rho = -0.58$		$\rho = -0.69$
	$N = 310$		$N = 310$
Results:	$t = -2.03$	Results:	$t = 1.62$
	DOF = 308		DOF = 308
	p-value = 0.04		*p*-value = 0.11

Note: Numbers have been rounded to 2 places for illustrative purposes. Greater than 2 place accuracy was used in all calculations.

Examination of the four comparisons of the difference score and non-difference score reliabilities shown in Tables 5 and 6 indicates a significant difference in reliabilities in three of the four cases investigated. Only the comparison of the reliabilities of the difference score and single statement measures of the net perceived return construct yielded no difference (p-value = 0.11). Because the other three cases investigated show a significant difference (p-values < 0.05) in difference score and non-difference score measures, it is maintained that there is sufficient evidence to reject Hypothesis 1. Therefore, we conclude that there is a difference in the reliabilities of the difference score and non-difference score measures of the latent business constructs measured in this study.

Validity Assessment

Nomological Validity Assessment. Lower bound reliability estimates and descriptive statistics for the items measuring overall impression and expected resale vale of the 4-door economy car are presented in Table 7.

The investigation of Hypotheses 2a through 2d was complicated by the fact that the correlations to be tested are not from independent samples. This necessitated the use of a jackknife procedure to provide unbiased estimates of the correlations (Balloun & Oumlil, 1986). A FORTRAN program written by Balloun and Oumlil (1986) provided n estimate (n = sample size) of unbiased correlations which were used to calculate sample means and standard deviations for each of the correlations of interest.

Hypotheses 2a through 2d were evaluated with single factor analysis of variance (ANOVA) to determine if there was any difference among the difference score and non-difference score methods with respect to nomological validity.

Examination of Table 8 indicates that there is no significant difference (p-value = 0.34) among the difference score, subjective difference and single statement measures of the net perceived return construct with respect to their correlation with the measure of overall impression of the 4-door economy car. Hypothesis 2a is not rejected at a reasonable level of significance.

Table 9 reveals no significant difference (p-value = 0.08) among the difference score, subjective difference and single statement measures of the disconfirmation of expectations construct with respect to their correlation with the measure of overall impression of the 4-door economy car at the 0.05 level of significance. Therefore, Hypothesis 2b is not rejected.

Table 10 does not indicate a significant difference (p-value = 0.47) among the difference score, subjective difference and single statement measures of the net perceived return construct with respect to their correlation with the measure of expected resale value of the 4-door economy car. Hypothesis 2c is not rejected.

Table 11 indicates that there is no difference (p-value = 0.42) among the difference, subjective difference and single statement measures of the disconfirmation of expectations construct with respect to their correlation with the measure of expected resale value of the 4-door economy car. Therefore, it is concluded that Hypothesis 2d should not be rejected.

Since Hypotheses 2a through 2d were not rejected at the 0.05 level of significance, Hypothesis 2 was not rejected. It is concluded that there is no difference in the nomological validity of the difference score and non-difference score measures of the latent business constructs measured in this study.

Table 7
Nomological Validity Investigation, Descriptive Statistics and Lower Bound of Reliability Estimates

	Overall Impression	Expected Resale Value
Mean	4.21	3.68
Standard Deviation	1.51	1.52
Skewness	-0.21	0.21
Kurtosis	-0.27	-1.24
Lower Bound of Reliability Estimate	0.27	0.14

Note: Lower bound of reliability estimates are the coefficient of multiple determinations (R^2) resulting from the regression of overall impression and expected resale value variables on all measures used in the study.

Convergent and Discriminant Validity Assessment. The convergent and discriminant validity of the difference score and non-difference score measures were evaluated using multitrait-multimethod matrix analysis (Campbell & Fiske, 1959). Specifically, the analysis of variance methodology suggested by Kavanaugh, MacKinney and Wolins (1971) was employed to provide structure to the multitrait-mulitmethod analysis of convergent and discriminant validity and to evaluate Hypotheses 3 and 4.

Table 8: Nomological Validity Investigation - Hypothesis 5

H_0: $p_{sin} = p_{dif} = p_{sub}$

H_1 = not all p_i are the same

ANOVA TABLE

Source	Sum of Squares	DF	Mean-Square	F	*p*-value
Method	3.08	2	1.54	1.07	0.34
Error	1338.55	927	1.44		

Results: Fail to reject H_0

	p_{sin}	p_{dif}	p_{sub}
Mean	0.28	0.32	0.18
Standard Deviation	1.21	1.23	1.16
Sample Size	310	310	310

Note: Numbers have been rounded to 2 places for illustrative purposes. Greater than 2 place accuracy was used in all calculations.

sin = single statement method, dif = difference score method, sub = subjective difference method

Table 9: Nomological Validity Investigation - Hypothesis 6

H_0: $p_{sin} = p_{dif} = p_{sub}$

H_1 = not all p_i are the same

ANOVA TABLE

Source	Sum of Squares	DF	Mean-Square	F	*p*-value
Method	8.79	2	4.39	2.57	0.08
Error	1584.14	927	1.71		

Results: Fail to reject H_0

	p_{sin}	p_{dif}	p_{sub}
Mean	0.39	0.25	0.49
Standard Deviation	1.22	1.06	1.59
Sample Size	310	310	310

Note: Numbers have been rounded to 2 places for illustrative purposes. Greater than 2 place accuracy was used in all calculations.

sin = single statement method, dif = difference score method, sub = subjective difference method

The evaluation of Hypotheses 3 and 4 required that the convergent and discriminant validity of the difference score and non-difference score measures of the latent business constructs be compared with the convergent and discriminant validity of the non-difference score measures of the latent business constructs. The multitrait-multimethod matrix containing the difference score, subjective difference and single statement measures of the net perceived return and disconfirmation of expectations constructs provided an overall view of the traits (constructs) and methods used in the study but it was not a form amenable to comparison of the convergent and discriminant validity of the difference and non-difference score measures necessary to evaluate Hypotheses 3 and 4. These comparisons necessitated the construction of three additional multitrait-multimethod matrices;

the first matrix containing difference score and subjective difference measures of the net perceived return and disconfirmation of expectations constructs, The second matrix, containing difference score and single statement measures of the net perceived return and disconfirmation of expectations constructs, and the third containing the multitrait-multimethod matrix of the subjective difference and single statement measures of the net perceived return and disconfirmation of expectations constructs. Tables containing these matrices are available upon request from the authors.

Table 10: Nomological Validity Investigation - Hypothesis 7

$H_0: p_{sin} = p_{dif} = p_{sub}$
H_1 = not all p_i are the same
ANOVA TABLE

Source	Sum of Squares	DF	Mean-Square	F	*p*-value
Method	208	2	1.04	0.75	0.47
Error	1292.10	927			

Results: Fail to reject H_0

	p_{sin}	p_{dif}	p_{sub}
Mean	0.20	0.30	0.21
Standard Deviation	1.21	1.15	1.23
Sample Size	310	310	310

Note: Numbers have been rounded to 2 places for illustrative purposes. Greater than 2 place accuracy was used in all calculations.
sin = single statement method, dif = difference score method, sub = subjective difference method

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Table 11: Nomological Validity Investigation - Hypothesis 8

$H_0: p_{sin} = p_{dif} = p_{sub}$
H_1 = not all p_i are the same
ANOVA TABLE

Source	Sum of Squares	DF	Mean-Square	F	*p*-value
Method	3.08	2	1.54	1.07	0.34
Error	1338.55	927	1.44		

Results: Fail to reject H_0

	p_{sin}	p_{dif}	p_{sub}
Mean	2.42	0.20	0.32
Standard Deviation	1.16	1.08	1.30
Sample Size	310	310	310

Note: Numbers have been rounded to 2 places for illustrative purposes. Greater than 2 place accuracy was used in all calculations.
sin = single statement method, dif = difference score method, sub = subjective difference method

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Consistent with the procedure employed by Kavanagh, MacKinney and Wolins (1971), the following three-way classification model was hypothesized to describe the data:

$$Y_{ijk} = \mu + \alpha_i + \beta_j + \gamma_k + (\alpha\beta)_{ij} + (\alpha\gamma)_{ik} + (\beta\gamma)_{jk} + \varepsilon_{ijk} \qquad (6)$$

where:

Y_{ijk}	= ratings of respondents for the traits by methods
α_i	= effect of respondent i = 1,2,...310
β_j	= effect of trait j = 1,2
γ_k	= effect of method k = 1,2,3
ε_{ijk}	= NID $(0, \sigma_\varepsilon)$

Using the methodology provided, analysis of variance tables with variance estimates and variance indexes were produced for each of the three multitrait-multimethod matrices mentioned above and appear in Tables 12, 13 and 14.

Table 12
Multitrait-Multimethod Matrix Analysis of Variance Table for Difference Score
and Subjective Difference Measures

Source	DF	SS	MS	F	Variance	Index
R (respondents)	309	586	1.90	3.32	0.33	.37
R X T (traits)	309	259	0.84	1.47	0.13	.19
R X M(methods)	309	219	0.71	1.24	0.07	.11
E (error)	309	176	0.57		0.57	

N (number of respondents) = 310
n (number of traits or constructs) = 2
m (number of methods) = 2

Note: The analysis of variance table was constructed, variance estimates were made, and the indexes were constructed with methodology consistent with and outlined in Kavanagh, MacKinney and Wolins (1971).

According to Kavanagh, MacKinney, and Wolins (1971), respondent variance indicates the overall amount of agreement, or convergence, among the measurement methods. Examination of the F statistics associated with the respondent variance in the ANOVA tables indicates significant convergence in each of the three cases at the 0.01 level of significance.

However, evaluation of Hypothesis 3 requires comparison of difference score convergent validity with that of the non-difference score methods. Unfortunately, this comparison cannot be made with a test statistic. As suggested by Kavanaugh, MacKinney and Wolins (1971), variance indexes were used for this comparison. Tables 12 and 13 contain the variance indexes for the difference score method's convergent validity with the subjective difference and single statement measures, respectively. These indexes are 0.37 and 0.53. Table 30 contains a variance index of 0.43 for the convergent validity of the two non-difference score methods. The average of the difference score measures, 0.45, is very close to the variance index of the non-difference score measures, 0.43. Logically, this would lead to the conclusion that there is no difference between the convergent

validity of the difference score measures and the convergent validity of the non-difference score measures. Hence, Hypothesis 3 is not rejected.

Table 13
Multitrait-Multimethod Matrix Analysis of Variance Table for Difference Score
and Single Statement Measures

Source	DF	SS	MS	F	Variance	Index
R (respondents)	309	693	2.24	5.53	0.46	.53
R X T (traits)	309	276	0.89	2.20	0.24	.38
R X M(methods)	309	145	0.47	1.16	0.03	.07
E (error)	309	125	0.41		0.41	

N (number of respondents) = 310
n (number of traits or constructs) = 2
m (number of methods) = 2
Note: The analysis of variance table was constructed, variance estimates were made, and the indexes were constructed with methodology consistent with and outlined in Kavanagh, MacKinney and Wolins (1971).

Table 14
Multitrait-Multimethod Matrix Analysis of Variance Table for Subjective Difference
and Single Statement Measures

Source	DF	SS	MS	F	Variance	Index
R (respondents)	309	569	1.82	4.08	0.35	.53
R X T (traits)	309	124	0.40	0.89	0.00	.38
R X M(methods)	309	407	1.32	2.91	0.43	.07
E (error)	309	140	0.45		0.45	

N (number of respondents) = 310
n (number of traits or constructs) = 2
m (number of methods) = 2
Note: The analysis of variance table was constructed, variance estimates were made, and the indexes were constructed with methodology consistent with and outlined in Kavanagh, MacKinney and Wolins (1971).

Kavanagh, MacKinney and Wolins (1971) maintain that discriminant validity is demonstrated by significant respondent by trait (construct) variance. The F statistics associated with the respondent by trait variance shown in the three ANOVA tables indicate significant discriminant validity in only the two cases involving difference scores. The multitrait-multimethod analysis of variance evaluation of the two non-difference score methods does not show significant (F = 0.89) discriminant validity. Therefore, it appears that the difference score discriminates itself from the non-difference score methods better than the two non-difference score methods discriminate between themselves. This is taken as evidence supporting the rejection of Hypothesis 4, and it is

concluded that there is a difference in the discriminant validity of the difference score and non-difference score measures of the latent business constructs measured in this study.

DISCUSSION

This research was focused on reliability and validity issues concerning the use of difference scores to measure latent business constructs. Four separate comparisons of difference score and non-difference score reliabilities were made. Only one of the four comparisons, that of the difference score and the single statement measures of the net perceived return construct (p-value = 0.11), indicates that there is not a statistically significant difference in the reliability of difference score and non-difference score measures. This was considered to be sufficient evidence to conclude that difference score and non-difference score measures were different with respect to reliability. This finding lends support to the idea that difference score measures have lower reliabilities than their non-difference score alternatives (Peter, Churchill & Brown, 1993; Johns 1981). However, it should be noted that only the reliability calculated for the difference score measure of the disconfirmation of expectations construct would be considered low by most researchers. All other measures used in the study had reliabilities above Nunnally's (1978) suggested standard of 0.70. Moreover, the reliability of 0.80 calculated for the difference score measure of the net perceived return construct is certainly high enough for practical research applications.

The nomological validity of the difference score and non-difference score measures of the latent business constructs was evaluated by testing for homogeneity of correlation with two theoretically related constructs: overall evaluation of the 4-door economy car and expected resale vale of the 4-door economy car. All hypothesis tests revealed no difference among the measurement methods with respect to correlation with the theoretically related constructs supporting the conclusion that the difference score and non-difference score measure used in this study are not different in nomological validity.

Multitrait-multimethod ANOVA analyses indicate that all measures exhibitied significant convergent validity at the 0.01 level of significance. Comparison of variance indexes did not provide evidence necessary to reject the hypothesis that difference score and non-difference score measures are different with respect to convergent validity.

The results of this study indicate that the difference score and non-difference score measures investigated are different with respect to discriminate validity. In fact, multitrait-multimethod ANOVA analysis indicates that the difference score measures exhibited better discriminant validity than the non-difference score measures. These findings conflict with literature maintaining that difference scores measures have lower discriminant validity than do non-difference scores measures (Peter, Churchill and Brown, 1993; Johns, 1981). The overall implication is that difference score measures should be considered as viable measurement alternatives, and must be given careful consideration when their use is warranted on theoretical grounds.

LIMITATIONS OF THE STUDY

This study is limited to two major factors (1) the generalizability of the sample to the population of difference score measures; and (2) the error present in the analyses. The net perceived return and disconfirmation of expectations constructs measured are but two of many latent business constructs that have been measured using difference score measures. The results from the evaluation of measures of two latent business constructs cannot be used to make inferences about the entire population of difference score measures of latent business constructs. The proper measurement technique should be determined for each unique situation. Difference score methods should not be discounted as viable alternatives when warranted for the comparison of two constructs, or traits without thorough empirical investigation.

The variance estimates developed in the multitrait-multimethod ANOVA analyses indicate that the amount of error variance is large in all three of the multitrait-multimethod matrix analyses. This means that the responses are very much dependent upon unknown sources of variation, and that any interpretation of results must be made with caution.

SUGGESTIONS FOR FUTURE RESEARCH

Given that the results of this study are not consistent with the conventional wisdom concerning the use of difference scores to measure latent constructs, it would seem prudent to replicate the study. First, an identical study could be undertaken to provide further validation of the results. Additional studies could also be performed to determine situations in which difference scores should or should not be used.

Additionally, an effort should be made to develop research projects that allow for the use of one of the more complex multitrait-multimethod analyses proposed by Bagozzi and Yi (1993, 1991) for the analysis of convergent and discriminant validity of difference score measures and non-difference score alternatives. It should be noted, however, that the proposals by Bagozzi and Yi (1993, 1991) require that more than three traits be measured by more than three methods, proving to be a very difficult study to design and execute.

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APPENDIX A
Scales used in this study

NET PERCEIVED RETURN

          Improbable   Probable

1.   I think that it is 1 2 3 4 5 6 7 that the purchase of a (brand) would lead to a financial loss for me because of such things as its poor warranty, high maintenance costs, and/or high monthly payments.

2.   As far as I'm concerned, if this financial loss happened to me it would be
               1 2 3 4 5 6 7
     Unimportant   Important
          Improbable   Probable

3.   I think that it is 1 2 3 4 5 6 7 that the purchase of a (brand) would lead to a social loss for me because my friends and relatives would think less highly of me.

4.   As far as I'm concerned if this social loss happened to me, it would be
               1 2 3 4 5 6 7
     Unimportant   Important
          Improbable   Probable

5.   I think that it is 1 2 3 4 5 6 7 that the purchase of a (brand) would lead to a performance loss for me because it would run extremely poorly.

6.   As far as I'm concerned, if this performance loss happened to me, it would be
               1 2 3 4 5 6 7
     Unimportant   Important
          Improbable   Probable

7.   I think that it is 1 2 3 4 5 6 7 that the purchase of a (brand) would lead to a psychological loss for me because it would not fit well with my self-image or self-concept (i.e., the way I think about myself).

8.   As far as I'm concerned if this psychological loss happened to me, it would be
               1 2 3 4 5 6 7
     Unimportant   Important
          Improbable   Probable

9.   I think that it is 1 2 3 4 5 6 7 that the purchase of a (brand) would lead to a physical loss for me because it would not be very safe or would become unsafe.

10.   As far as I'm concerned, if this physical loss happened to me, it would be
               1 2 3 4 5 6 7
     Unimportant   Important
          Improbable   Probable

11.   I think that it is 1 2 3 4 5 6 7 that the purchase of a (brand) would lead to a loss of convenience for me because I would have to waste a lot of time and effort getting it adjusted and repaired.

12.   As far as I'm concerned, if this loss of convenience happened to me, it would be
               1 2 3 4 5 6 7
     Unimportant   Important
          Improbable   Probable

13.   I think that it is 1 2 3 4 5 6 7 that the purchase of a (brand) would lead to a financial loss for me because of such things as its fine warranty, low maintenance costs, and/or reasonable monthly payments.

14.   As far as I'm concerned, if this financial gain happened to me it would be
               1 2 3 4 5 6 7
     Unimportant   Important
          Improbable   Probable

15.   I think that it is 1 2 3 4 5 6 7 that the purchase of a (brand) would lead to a social loss for me because my friends and relatives would think more highly of me.

16.   As far as I'm concerned if this social gain happened to me, it would be

        1 2 3 4 5 6 7

Unimportant   Important

   Improbable   Probable

17.   I think that it is 1   2   3   4   5   6   7 that the purchase of a (brand) would lead to a performance gain for me because it would run extremely well.

18.   As far as I'm concerned, if this performance gain happened to me, it would be

        1 2 3 4 5 6 7

Unimportant   Important

   Improbable   Probable

19.   I think that it is 1   2   3   4   5   6   7 that the purchase of a (brand) would lead to a psychological gain for me because it would fit in well with my self-image or self-concept (i.e., the way I think about myself).

20.   As far as I'm concerned if this psychological gain happened to me, it would be

        1 2 3 4 5 6 7

Unimportant   Important

   Improbable   Probable

21.   I think that it is 1   2   3   4   5   6   7 that the purchase of a (brand) would lead to a physical gain for me because it would be very safe and would remain safe.

22.   As far as I'm concerned, if this physical gain happened to me, it would be

        1 2 3 4 5 6 7

Unimportant   Important

   Improbable   Probable

23.   I think that it is 1   2   3   4   5   6   7 that the purchase of a (brand) would lead to a gain in convenience for me because I would not have to waste much time and effort getting it adjusted and repaired.

24.   As far as I'm concerned, if this gain in convenience happened to me, it would be

        1 2 3 4 5 6 7

Unimportant   Important

NET PERCEIVED RETURN--SUBJECTIVE COMPARISON

1.   The purchase of car x is 1   2   3   4   5   6   7 to result in financial gain for me than it is a financial loss for me due to such things as its good warranty, low maintenance costs, and/or low monthly payments.

2.   The purchase of car x is 1   2   3   4   5   6   7 to result in a social gain for me than it is a social loss for me because my friends and relatives will think more highly of me.

3.   The purchase of car x is 1   2   3   4   5   6   7 to result in a performance gain for me than it is a performance loss for me because the vehicle would run extremely well.

4.   The purchase of car x is 1   2   3   4   5   6   7 to result in a psychological gain for me than it is a psychological loss for me because the vehicle would fit in well with my self-image or self- concept (i.e., the way I think about yourself).

5.   The purchase of car x is 1   2   3   4   5   6   7 to result in a physical gain for me than it is a physical loss for me because it would be very safe and would remain safe.

6.   The purchase of car x is 1   2   3   4   5   6   7 to result in a gain in convenience for me than it is a loss of convenience for me because I would not have to waste much time and effort getting it adjusted and repaired.

        Measured 1 to 7 scale where: 1 = Less Likely, 7 = More Likely

SUBJECTIVE DISCONFIRMATION OF EXPECTATIONS

1. Car x would be a 1   2   3   4   5   6   7 purchase than the typical 4-door economy car because of such things as its good warranty, low maintenance costs, and/or low monthly payments.
2. My friends and relatives would think 1   2   3   4   5   6   7 highly of me if purchased car x rather than a typical 4-door economy car.
3. Car x's performance (i.e., the way it runs) would be 1   2   3   4   5   6   7 than the typical 4-door economy car.
4. Car x would fit my self-image or self-concept (i.e., the way I think about myself) 1   2   3   4   5   6   7 than the typical 4-door economy car.
5. Car x would be 1   2   3   4   5   6   7 safe than the typical than the typical 4-door economy car.
6. Car x would inconvenience me 1   2   3   4   5   6   7 than the typical 4-door economy car because of the time and effort necessary to get it adjusted and repaired. (negatively scored)

    Item 1 scored on a scale of 1 to 7, where: 1 = Much Poorer, 7 = Much Better Items
    3 and 4 scored on a scale of 1 to 7, where: 1 = Much Worse, 7 = Much Better
    Items 2, 5 and 6 scored on a scale of 1 to 7, where: 1 = Much Less, 7 = Much More

DISCONFIRMATION OF EXPECTATIONS

Expectations

1. A typical small 4-door economy car would be poor choice because of such things as their poor warranties, high maintenance costs, and/or high monthly payments.
2. I think that the purchase of a typical small 4- door economy car would cause my friends and relatives to think less highly of me.
3. I think that the purchase of a typical small 4- door economy car would cause a performance loss for me because it would run extremely poorly.
4. I think that the purchase of a typical small 4- door economy car would not fit well with my self-image or self-concept (i.e., the way I think about myself) .
5. I think that a typical small 4-door sedan would not be very safe or would become unsafe.
6. I think that the purchase of a typical small 4- economy car would inconvenience me because I would have to waste a lot of time and effort getting it adjusted and repaired.

    Measured on scale of 1 to 7, where: 1 = Strongly, Disagree 7 = Strongly Agree

Perceptions

1. The purchase of car x would be a poor choice because of such things as their poor warranties, high maintenance costs, and/or high monthly payments.
2. Purchase of a car x would cause my friends and relatives to think less highly of me.
3. Purchase of a car x would cause a performance loss for me because it would run extremely poorly.
4. Purchase of a car x would not fit well with my self-image or self-concept (i.e., the way I think about myself) .
5. Car x would not be very safe or would become unsafe.
6. Purchase of a car x would inconvenience me because I would have to waste a lot of time and effort getting it adjusted and repaired.

    Measured on scale of 1 to 7, where: 1 = Strongly, Disagree 7 = Strongly Agree

ADDITIONAL ITEMS

1.   If I were to purchase a small 4-door economy, car x would be an excellent choice
2.   I expect car x to have a very high resale value.

        Measured on scale of 1 to 7, where: 1 = Strongly, Disagree 7 = Strongly Agree

APPENDIX B

TABLES AVAILABLE FROM THE AUTHORS

        Regarding the Disconfirmation of Expectations, the tables presenting descriptive statistics, inter-item correlations and coefficient alphas for the expectation (E_i) and perception (P_j) items summed to develop the expectation (EXP) and perception (PER) components of the difference score measure of the disconfirmation of expectation (DISC) construct and the table presenting the descriptive statistics, inter-item correlations and coefficient alpha for the items (SD_i) that were summed to form the subjective difference measure of the disconfirmation of expectations construct (SDISC).

        Regarding Net Perceived Return, the table presenting descriptive statistics, inter-item correlations and alphas for the RET_i measures that were summed to form the overall perceived return (OPRe) component used in the construction of the difference score measure of the net perceived return (NPRe) construct and the tables presenting the descriptive statistics, inter-item correlations and alphas for the probability of gain (PG_i) and importance of gain (IG_i) measures that were used to calculate the RET_i items. Note that the probability of gain (PG_i) and importance of gain (IG_i) items are not used as summative scales in the study. Coefficients alpha merely provide consistent information concerning all measures used in the study. The table presenting the descriptive statistics, inter-item correlations and alphas for the RSK_i measures that were summed to create the overall perceived risk measure (OPR) component necessary to construct the difference score measure of the net perceived return (NPRe) construct and the tables presenting the descriptive statistics, inter-item correlations and alphas for the probability of loss (Pl_i) and importance of loss (IL_i) measures that were used to calculate the RSK_i items. Again, note that the probability of loss (Pl_i) and importance of loss (IL_i) items are not used as summative scales in the study. Coefficients alpha merely provide consistent information concerning these measures. The table presenting the descriptive statistics, inter-item correlations and alpha for the $ISLG_{ij}$ measures that were summed to form the subjective difference measure of the net perceived return constructs ($SNPRe_j$) and the tables presenting the descriptive statistics, inter-item correlations and alpha for the I_{ij} and SLG_{ij} items used to construct the $ISLG_{ij}$ measures.

THE ROUTINIZATION OF WEB-BASED SUPPLIER DIVERSITY INITIATIVES

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ABSTRACT

The Web facilitates the initiation and development of relationships between firms in a supply chain. This study of Web-based supply chain links examines supplier diversity initiatives on the Web sites of the Fortune 500. It develops a measure of supplier diversity routinization based on innovation diffusion and routinization research. The study finds that few (15.6%) Fortune 500 firms use their public Web site to publicize supplier diversity. Current users of Web-based supplier diversity are categorized by diffusion theory as innovators and early adopters. The sites of the largest firms are most likely to mention supplier diversity. However, among all sites that mention supplier diversity, the degree of routinization - - the number of different categories of supplier diversity comments - - is relatively low and does not vary by firm size or industry. Thus, Web-based supplier diversity is marked by low levels of adoption and routinization.

INTRODUCTION

Links between trading partners are becoming Web enabled. For example, electronic data interchange (EDI), which reduces processing errors, lowers operating costs, and shortens replenishment cycles between trading partners (Young, Carr, & Rainer, 2000), is moving to the Web (Gilbert, 2003). Firms realize significant time and cost savings as electronic relationships are Web enabled by e-procurement (Cohen, 2002). The Web is a rapidly growing channel for business-to-business (B2B) commerce, forecasted to reach $1 trillion in the U.S. in 2004 (Berkowitz, 2003). Forrester Research finds Web-based e-procurement growing rapidly among the Fortune 500 for both direct (e.g., manufacturing related) and indirect (e.g., supply related) goods (Tedeschi, 2004). Given the dramatic growth occurring in B2B e-commerce, and in related support systems, Web-based supplier communications should be studied.

SUPPLIER DIVERSITY

Firms are Web enabling supplier communications and procurement efforts, including supplier diversity programs which develop trading partner relationships with small, women-owned, and minority businesses. Supplier diversity is an important component of corporate diversity

programs that address diverse constituencies in a global marketplace (Wentling & Palma-Rivas, 2000). The business case for supplier diversity is not based on altruistic motives alone, but on the belief that a firm's supplier base should be as diverse as its customer base (Purchasing, 1998), and because it is simply good for business (Armstrong, 2004; Daniels, 2004). Web-based supplier diversity should be researched because of its competitive impact, the potential the Web has for reaching diverse supplier prospects, and because it is largely unstudied but represents a critical subset of B2B relationships.

The study reported here focuses on how large firms use public Web sites to communicate with and attract diverse suppliers. Diverse suppliers include small or disadvantaged firms headed by minorities, women, or disabled veterans. Using the Web to communicate with diverse firms is justified because the gender and racial mix of Web users in the U.S. is close to the race and gender composition of the overall population (Thompson, 2000a, 2000b). In addition, nearly half of the U.S.'s largest minority-owned firms have a Web site (Hernandez, 2002). Purchasing from diverse suppliers helps make a firm's supplier base as diverse as the different types of customers it deals with (Reese, 2001) because an effective way to link to minority customers is to give business to minority suppliers (Armstrong, 2004).

The minority segment of the U.S. population, and its buying power, is growing rapidly (Reese, 2001), minorities make-up 27% of the U.S. population (MBDA), and much of the U.S. labor force growth is among minorities (Milken, 2000). The number of small-to-medium sized enterprises in the U.S. is growing quickly (Fields, 2001). The number of minority-owned firms is growing faster than non-minority firms and sales per employee grow faster at minority firms than at the Fortune 500 (Milken, 2000). Blacks represent 66% of minority business enterprises, Asian-Americans 21%, and Hispanics 11% (Davis, 2004). Clearly the minority population in the U.S., as mirrored by minority and women-owned small business, is a growing and influential aspect of the economy. Supplier diversity programs are, therefore, important because they enable large firms to engage in commerce with a rapidly growing segment of the population, and partnering with minority-owned enterprises is one way to learn about minority consumers (Reese, 2001). However, minority firms get only 3.5% of corporate purchasing (Hernandez, 2002; Reese, 2001); women-owned firms receive less than 3% of Fortune 500 purchases (div2000.com) and less than 2.5% of Pentagon contracts (Fields, 2001). In addition, although they have Web links themselves, small-to-medium sized businesses cannot be certain that their suppliers will support e-procurement (Tedeschi, 2004).

Supplier diversity is important because it is a bottom-line business issue, not simply a social issue (Walkup, 1999). There are several reasons for supplier diversity (Young, 2001). Supplier diversity enables the firm to be a more interesting place to shop, and helps the firm understand and attract diverse customers. These programs provide competitive advantage by supporting continuous improvement of products and processes. It is a way for firms to invest in and help the communities they operate in, to express concern for the public good, and it's the right thing to do. U.S. firms that sell to the federal government must demonstrate a diverse supplier base (Nolan, 1999).

Procurement is becoming electronic (Hernandez, 2002; Reese, 2001). E-procurement negatively affects the competitiveness of minority-owned firms due to contract bundling, which increases average contract size, and because of the technical expertise required (Fields, 2001; Hernandez, 2002; Reese, 2001; Tedeschi, 2004). It impacts the retention of minority businesses that have supplier relations with buying firms, but to attract diverse suppliers buying firms must develop outreach programs that may include electronic channels such as public Web sites.

This study examines supplier diversity on Fortune 500 public Web sites and measures the routinization of those initiatives. The theoretical backing is diffusion theory and innovation routinization. This paper reviews information systems (IS) research based on diffusion theory, measures Web-based supplier diversity, and discusses its current usage. The differentiating characteristics of this paper are applying innovation routinization to a Web-based IS, and integrating diversity into an IS study.

SUPPORTING RESEARCH

This study is supported by three streams of research: electronic supply chain links, corporate supplier diversity programs, and innovation diffusion theory. The first area studies the role of the Web in connecting trading partners. Diversity studies examine one aspect of supply chains - - the need for a diverse base of suppliers. Innovation diffusion provides the theoretical backing and measurement variables for this study.

ELECTRONIC SUPPLY CHAIN LINKS

B2B commerce is Web-enabled by public sites and private extranets. Firms use public Web sites for trading partner communication (Young & Benamati, 2000). Some industries have rapidly Web-enabled supply chain links (Carbone, 2000), others have moved slowly (CSC, 2000), and the Web is replacing EDI for some B2B transactions (Baron, Shaw, & Bailey, 2000). Establishing B2B links involves business relationships and the costs of managing electronic communications (Young, Carr, & Rainer, 2000). However, electronic B2B links are often driven by the large, buying firm in the supply chain (Tedeschi, 2004).Benefits of Web-enabled B2B commerce include real-time business processes (Fingar, 2000), improved inventory management (CSC, 2000), eliminating proprietary software and VANs for EDI (Carbone, 2000; Gilbert, 2003), transaction cost reductions (Brunelli, 2000), and service improvements (Lancioni, Smith, & Oliva, 2000).

SUPPLIER DIVERSITY STUDIES

Diversity is defined in terms of race, gender, ethnicity, age, national origin, disability, and other characteristics; more generally it means all the ways people differ (Wentling & Palma-Rivas, 2000). The National Minority Supplier Development Council (www.nmsdcus.org), Women's

Business Enterprise National Council (www.wbenc.org), and Small Business Administration (www.sba.gov) define a minority and women-owned business enterprise (MWBE) as at least 51% owned, controlled, and operated by African, Hispanic, Asian, or Native Americans, or non-minority women. The agencies maintain a database of certified firms and provide certification so businesses can prove they are minority owned. Certification involves screening, interviews, capability studies, examination of financial statements, and site visits.

Supplier diversity programs feature special-function organizational units, programs for MWBE outreach and assistance, expectations of down-stream trading partners regarding MWBE efforts, clearly defined metrics, and benchmarking to identify best practices (Morgan, 2002). Supplier diversity is promoted by a program office with a director and other personnel (Carter, Auskalnis, & Kechum, 1999) to assist prospects with application and certification. They post lists of products/services that are purchased, host open houses, and participate in industry forums and trade fairs. Some firms mentor MWBEs to meet contract requirements. U.S. DOD contractors participate in the agency's mentor-protégé program, and firms with larger Federal contracts are required to develop minority supplier programs (Armstrong, 2004). Others assist MWBEs as second-tier suppliers with contacts to primary vendors; some have second-tier MWBE reporting requirements written into large supplier contracts. Success measures include the percentage of total procurement spend with MWBEs and the number of minority vendors in the purchasing database (Carter, Auskalnis, & Ketchum, 1999).

Supplier diversity has received scant mention in prior workplace diversity studies, and prior literature reviews of minority supplier research find that few academic studies address the topic (Carter, Auskalnis, & Ketchum, 1999; Krause, Ragatz, and Hughley, 1999). One study among Fortune 500 diversity managers briefly mentioned minority suppliers, but did not mention the Web for supplier communication (Wentling & Palma-Rivas, 2000). Fine (1996) emphasized the importance of multi-cultural organizations for a multi-cultural world, but her study focused on issues other than supply chain and trading partners.

Some themes emerge from academic minority supplier studies. Minority supplier programs are most successful when: buyers assist suppliers with bidding procedures, and buying-firms participate in trade fairs, develop performance metrics and minority supplier spending targets (Dollinger, Enz, & Daily, 1991). Top management support and setting goals for minority supplier programs are important (Carter, Auskalnis, & Ketchum, 1999). Supplier development - - improving the performance or capabilities of a supplier -- is performed by large firms and includes certification, supplier site visits, and awards (Krause, 1997). Minority suppliers must be able to compete in the areas of quality, timely delivery, and competitive price (Krause, Ragatz, & Hughley, 1999) without set asides, price preferences, or late delivery (Carter, Auskalnis, and Ketchum, 1999). Minorities face supply base reductions by buyers (Krause, Ragatz, & Hughley, 1999). Bundling and preferred supplier programs increase the importance of second-tiering where the primary supplier generates much of the minority opportunity (Morgan, 2002; Munk, 2003; Weaver, Stovell, & Romney, 2003).

INNOVATION DIFFUSION IN IS RESEARCH

Innovation diffusion theory tracks the spread of a new idea or practice within a single firm or across an industry. It explains the adoption and implementation of innovations, ideas or practices new to an adopting organization (Rogers, 1995), or are the first/early usage by an organization (Nord & Tucker, 1987). Adoption proceeds through stages, including evaluation and implementation (Zaltman, et al., 1973), and has been applied in various disciplines for following an innovation through those stages (Rogers, 1995). The implementation stage is composed of sub-stages, including routinization, which is the process by which the innovation becomes part of the normal activity and accepted routine of an organization (Cooper & Zmud, 1990) and is not viewed as something new or unusual (Yin, 1979).

Diffusion theory is rooted in various research disciplines, including rural sociology, geography, medical sociology, cultural anthropology, and industrial economics (Gatignon & Robertson, 1985). The theory has been used for some time to support the adoption of innovations, such as information technology (see below), that are discrete and tangible. In addition, in recent years innovation diffusion has been applied to the study of social issues such as living practices prior to marriage (Nazio & Blossfeld, 2003), quitting smoking (Redmond, 1996), policy innovations among state governments (Mintrom & Vergari, 1998), and the use of county administrators (Apperson & Wikstrom, 1997). Innovation diffusion also supports the study of trans-border data privacy laws, which links a technology (i.e., e-commerce) and the social concerns of privacy (Rudraswamy & Vance, 2001). The topic of this paper, supplier diversity content on corporate Web sites, combines these two areas of study- - tangible innovations and social issues - - in that it examines a specific technology (i.e., Web content), which has both social and business implications, as described earlier in this literature review.

Diffusion studies examine aspects of innovation adoption, including attributes of the innovation (e.g., relative advantage, complexity, observability), characteristics of the adopting organization (e.g., size, centralization), and the rate of adoption (Hage & Aiken, 1970; Rogers, 1995; Zaltman, et al. 1973). The rate of adoption is the speed with which a group adopts an innovation (Rogers, 1995). The rate of adoption is of interest in the study being reported here because it notes the presence or absence of an innovation, supplier diversity content on a Web site, across a large and influential population of adopters - - 500 corporations. Organizational size is positively related to innovativeness, and is a surrogate for total resources in the firm (Nord & Tucker, 1987; Nystrom & Starbuck, 1981; Rogers, 1995). Adoption follows a bell-shaped curve with the earliest adopters the most innovative. Innovators are the first 2.5%, early adopters the next 13.5%; the early (34%) and late (34%) majority follow. The last 16% are laggards (Rogers, 1995).

Diffusion theory supports information systems (IS) research. Cross-industry IS studies, the focus of this paper, applying diffusion theory include Ramamurthy & Premkumar, 1995, Lai, 1997, Grover, 1993, and Grover & Goslar, 1993. Single firm/industry IS diffusion studies include Dos Santos and Peffers (1998), George et al. (1992), and Premkumar et al. (1997). Other IS diffusion

studies include windows technology (Karahanna, et al. 1999), telework (Ruppel & Howard, 1998), automatic teller machines (Dos Santos & Peffers, 1998), telephone networks (Flynn & Preston, 1999), and productivity tools (Grover et al., 1998). IS studies examining the degree of routinization or extent of IT implementation include: Lai (1997) - - ISDN, Premkumar, et al. (1994) - - EDI, Zmud & Apple (1992) - - scanners, and Cooper & Zmud (1990) - - MRP.

A few studies link innovation diffusion and the Web. Liao, et al. (1999) applied the theory to virtual banking and Lee (1998) to Internet-based financial transactions. Likewise, few studies examine the impact of the Web on supply chain relationships. Lancioni, et al. (2000) note that using the Internet for managing supply chains is new and few studies have been done. Baron, et al. (2000) describe the impact of the Web on procurement and supplier interaction; a retail technology study found that large retailers have been slow to use the Web to interact with trading partners (CSC, 2000).

In summary, innovation diffusion provides theoretical support for IS adoption, implementation, and routinization. However, few studies have examined the role of the Web in supply chain collaboration, or have related innovation diffusion to Web-based ISs, and no study to date has applied these concepts to Web-based diversity initiatives.

RESEARCH QUESTIONS

The lack of research into routinization of Web-based supply chain links argues for a study to answer questions regarding the extent of adoption of Web-based supplier diversity, and the supplier diversity content on those sites. That content, in turn, provides items to measure the routinization of Web-based supplier diversity. Therefore, this study answers the following questions:

RQ1:   What is the percentage of corporate Web sites with supplier diversity content?
RQ2:   What is the content of corporate Web-based supplier diversity initiatives?
RQ3:   What is the degree of routinization of Web-based supplier diversity initiatives?
RQ4:   Does the routinization of Web-based supplier diversity vary by firm size?
RQ5:   Does the routinization of Web-based supplier diversity vary by industry?

The first two questions are descriptive (i.e., "how many" and "what"). Fortune 500 sites with supplier diversity content were counted (RQ1), and the supplier diversity content on those sites was categorized (RQ2). The "Methodology" section explains the measure for supplier diversity routinization (RQ3). Categorizing diversity by firm size (RQ4) and industry (RQ5) identifies supply chains that are early adopters of Web-based links.

METHODOLOGY

The public Web site of every Fortune 500 firm was examined. These sites are a valuable resource for studying supplier diversity because of the size of the firms, their public exposure and

responsiveness to diverse constituencies, and the potential for them to have well-established diversity programs exclusive of the Web. These firms have the resources to develop diversity initiatives and the channel influence to sustain them. The Web is a component of corporate diversity, and is a recent innovation in initiating and maintaining relationships with various constituencies. A form (Appendix) was developed, tested, and modified to catalog Web content relating to supplier diversity. Items on the form were influenced by previous supply chain and diversity studies, by site visits to the 50 largest firms on the list, and by the researchers' experience. The form went through several modifications during development to insure complete content coverage.

Whenever available, the site's search engine was used to identify key terms during the site visits: supplier, vendor, procurement, diversity, and minority or women-owned or small business. In the absence of a search engine a page-by-page search was conducted. The acronym on the sites for diverse suppliers was "MWBE" - - minority and women-owned business enterprises; some include disabled veterans and small or disadvantaged businesses as MWBEs.

The data collection and analysis process followed the qualitative methodology of Strauss (1987) for examining textual data. During each site visit all the Web pages relating to supplier diversity were printed. Those pages were content analyzed by identifying supplier diversity items. Occurrences of supplier diversity routinization items, which are explained in the next section, were coded on the printed pages. The number of each variable across all sites were entered on a tabulation sheet and totaled to provide a routinization score. This scoring process matched procedures in previous IS routinization studies. Data collection was based on the 2000 Fortune 500 list.

The data are a census because the Fortune 500 is a population, eliminating parametric inferential procedures related to test of equality of location and variability measures. Population tests move from statistical inference - - based on sample results - - to practical significance, based on comparative and associative population measures. This analysis includes counts, statistical summaries, nonparametric inference, and association analysis to measure practical significance.

MEASURING WEB-BASED IT ROUTINIZATION

After adopting an information technology (IT) innovation, firms begin installation and maintenance. Processes may be changed because of the new system, individuals accept and use the technology, it becomes routinized, and the firm measures increased effectiveness because of IT infusion (Cooper & Zmud, 1990). Innovations are routinized by budgets, formal personnel classifications, training, rules and procedures, and maintenance operations (Yin, 1979). These categories are variables used in studies of innovation routinization.

Yin's (1979) seminal work measured the degree of routinization by a count of the number of budget and other cycles for each innovation studied, including computer systems. Zmud & Apple (1992) measured the degree of routinization of electronic scanners by adapting the variables of Yin and totaling the number of appearances of each variable. Grover & Goslar (1993) measured the extent of implementation of telecommunication technologies on a scale. Premkumar, et al. (1994)

used a scale to measure the extent of EDI integration. Thus, scales or counts are common measures of innovation routinization in IS studies. This study measures routinization by employing a count of routinization items on Web pages.

MEASURING SUPPLIER DIVERSITY ROUTINIZATION

This study adapts four categories of variables from Yin (1979) - - budgets, personnel, training, and rules/procedures - - to determine the routinization of Web-based supplier diversity. These are the same four routinization variables used in the Zmud & Apple (1992) IS study.

> For budgets this study identifies two items - spending on diversity initiatives and multiple budget cycles represented by a start date for the diversity program.

> Personnel classifications include a title for the diversity program manager, and any additional supplier diversity job classifications or titles.

> Training introduces an innovation to an organization and it shows commitment for the innovation. Items for expressed commitment to supplier diversity are: references on the Web site to the importance of supplier diversity, and statements about how personnel treat potential diverse suppliers.

> Four items are used for rules and procedures: requiring supplier certification by an outside agency, specifying the use of access technologies such as EDI, describing procedures by personnel for evaluating diverse suppliers, and expectations regarding quality, financial stability, or geographic coverage.

Content validity is the extent to which a measure mirrors a domain of knowledge (Carmines & Zeller, 1979). There are two ways to insure the validity or completeness of the content in this study. First, variables (e.g., budgets, personnel) are patterned after studies of innovation diffusion and IS routinization. Second, the items on the form were based on careful selection and testing of content from studies in e-commerce, innovation diffusion, innovation routinization, and supplier diversity.

FINDINGS

Public Web sites are common, but mentioning supplier diversity on them is not. All but five of the firms had a public Web site, but only 38/495 (7.7%) use the site to describe a supplier diversity program. Another 24 (4.8%) ask that diverse supplier prospects "call us" and do not describe the program. Fifteen mention supplier diversity without contact information. Thus, 77 sites (15.6%) have supplier diversity content, which is similar to the percentage (14.6%) of minority firms in the U.S. (MBDA). Supplier diversity content appears in two locations. It is listed with

corporate-wide supplier comments (e.g., procurement practices), or with the firm's diversity statement that discusses the importance of diversity among customers, employees, and suppliers.

SUPPLIER DIVERSITY CONTENT

Web-based supplier diversity content (Table 1) includes: application forms, technology requirements such as bar coding, requests for financial statements, definitions for minority businesses, and certification instructions. Some sites have multiple pages for this content; others state that supplier diversity is important and request the prospective supplier mail a letter of introduction or phone for more information.

Table 1 Web-based Supplier Diversity items (n = 77)		
Supplier Diversity Item	#	%
MWBE certification	48	62.3
E-application form	41	53.2
Submission of financials	34	44.2
List MWBE categories	33	42.9
Supplier diversity budget information	25	32.5
URLs for certifying agencies	22	28.6
Diversity letter from corporate officer	21	27.3
Evidence of technical/operational capabilities	20	26.0
Awards/case studies	18	23.4
Use of second-tier suppliers	16	20.8
Chi-square test comparing observed values to a normal distribution was significant at the .005 level. Computed chi-square value was 37.12 (table value at .005 level, 9 degrees of freedom = 23.59).		

ROUTINIZATION ITEMS

The most frequent supplier diversity routinization items (Table 2) are statements about the importance of supplier diversity (item 3a) and certification requirements (item 4a). Over half of the sites with MWBE content list a formal title and/or name for the supplier diversity officer. "Outreach participation" (item 3b) means the firm describes its attendance at forums or small business job fairs. "Operational requirements" (item 4b) include specification of access technologies (e.g., EDI), quality standards such as ISO 9000, and product label requirements by retailers.

Table 2 **Supplier Diversity Routinization Items (n = 77)**		
Category and Items	#	%
1. Budgets		
1a. Total dollars or % of procurement spent on supplier diversity	25	32.5
1b. Multiple budget cycles, list supplier diversity program start date	25	32.5
2. Personnel		
2a. Title for supplier diversity program manager, or listed contact name	39	50.6
2b. Multiple job classifications for supplier diversity personnel	15	19.5
3. Expressed Commitment to Supplier Diversity		
3a. Corporate diversity statement, officer letter about its importance	68	88.3
3b. Describe treatment of diverse suppliers, outreach participation	35	45.5
4. Rules and Procedures		
4a. Require certification	48	62.3
4b. Operational requirements	20	26.0
4c. Formal evaluation procedures for diverse suppliers	17	22.1
4d. On-line application forms	41	53.2
Chi-square test comparing observed values to a normal distribution was significant at the .005 level. Computed chi-square value was 72.98 (table value at .005 level, 9 degrees of freedom = 23.59).		

DEGREE OF ROUTINIZATION

Routinization was measured following Yin and prior IS studies. Table 3 summarizes the routinization scores. A Chi-square test ($p < .005$) shows the routinization scores are not normally distributed. Sites with one to three routinization items have a low degree of routinization; 30/77 (39.0%) are rated low. Six (7.8%) have a high degree of routinization and 41 (53.2%) are rated moderate. The mean routinization score is 4.32 (median = 4), indicating the sites contain four of the ten items. This relatively low score suggests that descriptions of Web-based supplier diversity are sparse.

Table 3: Degree of Supplier Diversity Routinization (n = 77)										
Count of routinization items	1	2	3	4	5	6	7	8	9	10
# of firms with each routinization score	7	7	16	15	11	10	5	2	2	2
Category total & percentage	30 (39.0%)			41 (53.2%)				6 (7.8%)		
Degree of Routinization:	Low			Moderate				High		

VARIATION BY COMPANY SIZE

Table 4 compares mean, median, mode, standard deviations, and correlations for ranking categories versus overall routinization scores. The distribution of mean, median, and mode is similar, and routinization scores change little, across ranking categories. The mean routinization score is 4.32, and the mean for ranking 1-250 is 4.3.

Table 4: Sites with Supplier Diversity Content by Firm Size (n = 77)							
	Fortune 500 Rank Category						
Measure	All	1-50	51-100	101-200	201-300	301-400	401-500
Count	77	20	16	14	12	11	4
Percent a	100.0	26.0	21.0	18.0	16.0	14.0	5.0
Percent b	15.4	40.00	32.0	14.0	12.0	11.0	4.0
Mean	4.3	4.4	4.4	4.1	4.7	4.0	4.3
Median	4.0	5.0	4.0	3.5	4.0	4.0	4.5
Mode	3.0	7.0	2.0	3.0	4.0	4.0	5.0
Std Deviation	2.1	2.3	2.5	2.6	1.9	1.3	1.0
Correlation	-0.02	-0.03	0.38	-0.23	0.22	0.13	0.08
a is the % of 77 routinization scores b is the % of 77 routinization scores relative to number of firms in the rank category.							

The Kruskal-Wallis (KW) procedure (Neter et al., 1985), which is similar to ANOVA but with relaxed distribution assumptions, yields a p-value > 0.90, implying no statistically significant difference between median routinization scores. (The procedure was applied to 76 randomly selected firms to simulate a sample for inferential interpretation and the p-value is the most conservative result from all possible samples.) Score variability measured by standard deviation is similar across categories. The Siegel-Tukey (ST) test (Gibbons, 1985) yields a p-value > 0.20 to test the equality of variance between firms ranked 1-50 versus 300-500. (The 300-500 range generates sufficient data for the test.) There is no statistically significant difference in routinization score variability between the highest and lowest ranking categories.

Firm size does not affect the degree of supplier diversity routinization. (The revenue of the smallest firm exceeded \$3 billion.) The correlation between ranking and routinization score is -0.02 (Table 4). The correlation between the six categories and routinization scores are low (0.03 to 0.38) indicating no significant relationship between ranking and routinization score. The percentage of firms in each ranking category (percent a in Table 4) reveals that the larger the firm, the greater the likelihood its site has supplier diversity content. The degree of routinization relative to the number of firms in each category (percent b in Table 4) supports this assertion (e.g., 40% of the top 50 firms,

32% of the next 50 firms, and so on, exhibit routinization). The Chi-square test rejects the null hypothesis of identical distributions of percents with p-values of 0.0460 and 0.0004, respectively.

The percentage of diversity items and firms in each category match (Table 5), supporting that routinization does not vary by firm size. For example, in category 1-200 216/333 (64.9%) of the items occur among those 50/77 (64.9%) firms. A Chi-square test of the association between ranking categories and routinization items (p = 0.996) does not reject the hypothesis of independence.

Table 5: Number of Supplier Diversity Items by Firm Size (n = 77)												
	Diversity Item (see Table 2 for Item descriptions)											
Fortune Rank	# Firms	1a	1b	2a	2b	3a	3b	4a	4b	4c	4d	Total
1-100	36	13	15	19	9	33	10	21	11	9	19	159
101-200	14	8	4	5	2	10	6	8	5	3	6	57
201-300	12	2	3	6	2	11	11	9	1	3	8	56
301-400	11	2	3	6	1	10	5	7	2	2	6	44
401-500	4	0	0	3	1	4	3	3	1	0	2	17
Total:	77	25	25	39	15	68	35	48	20	17	41	333

Large-firm sites have a disproportionate number of low routinization scores (Table 6). Firms 1-100 are 53.3% of low routinization sites and 1-200 are 76.7%. For both the percentage of low scores is higher than the study average (39.0%), and the percentage of moderate scores is lower (53.2%). More large firm sites than the study average have supplier diversity content, but the number of items is limited compared to smaller firms. There are nearly 2.5 times as many sites with supplier diversity content than the expected value (15.4) among 1-100 (46.8% of the 77 firms), but there is less than a third of the level expected among 401-500 (5.2% of the firms).

Table 6: Routinization Scores by Firm Size (n = 77)				
	Degree of Routinization			
Fortune Ranking	Low (# / %)	Moderate (# / %)	High (# / %)	Total
1-100	16 / 44.4	17 / 47.2	3 / 08.3	36
101-200	7 / 50.0	5 / 35.7	2 / 14.3	14
201-300	2 / 16.7	9 / 75.0	1 / 08.3	12
301-400	4 / 36.4	7 / 63.6	0	11
401-500	1 / 25.0	3 / 75.0	0	4
Total:	30 / 39.0	41 / 53.2	6 / 7.8	77
Chi-square test comparing observed values to a normal distribution was significant at the .005 level. Computed chi-square value was 38.13 (table value at .005 level, 4 degrees of freedom = 14.86).				

VARIATION BY INDUSTRY

The 77 firms are in 29 different industries, including: gas and electric utilities (9 firms), general merchandisers (6), computers and office equipment (6), telecommunications (5), and aerospace (5). The highest-count industry (gas and electric utilities) is 12% of the sites. The mix of industries shows that diversity routinization does not vary by industry (a Chi-square test, .005 level, shows no variance from a normal distribution).

ANSWERING THE RESEARCH QUESTIONS

Only 15.6% of Fortune 500 Web sites have supplier diversity content, answering Question 1. Table 1 answers Question 2 by listing the supplier diversity content on these sites. There is a moderate degree of routinization of Web-based supplier diversity content (Question 3). The degree of Web-based supplier diversity routinization does not vary by company size (Question 4) or industry (Question 5).

DISCUSSION

The public Web sites of large corporations are barely utilized for promoting supplier diversity, although this is one aspect of trading partner and supply chain interaction for which the Web is well suited. Building a diverse supplier base may be important to many of these firms, but this study finds that the Web is not a heavily used component of corporate supplier diversity initiatives.

The largest Fortune 500 corporations are most likely to have Web-based statements about supplier diversity, but firm size is not related to the degree of routinization because the sites of the biggest firms in the study exhibited no more supplier diversity routinization than the smallest firms. There is a lack of breadth in supplier diversity items (i.e., a disproportionate number of low routinization scores) among the largest firms in this study. Has Web-based supplier diversity been overlooked by Web site planners, or are there other Web site content issues that are being given greater strategic priority within the larger firms?

Much of the Web-based supplier diversity content is these large firms publishing their expectations, or requirements, for issues such as certification, financial stability or operations, and describing MWBE categories. From Table 1 we learn that these large firms demand certification, require applicants to submit proof of financial stability, and require evidence of technical and operational capabilities. These firms do not relax demands for competitive prices, and timely and consistent delivery, simply to attract diverse suppliers. Less of that Web site content deals with "transactions" such as electronic application forms. Given the early stage of adoption for Web-based supplier diversity communications, this emphasis on publishing over transactions is expected because content publishing is easier to accomplish.

The most frequently mentioned supplier diversity item (88.3%) among firms with supplier diversity communication on their Web sites is the importance of these efforts; they often use a letter from the company chairman or president as an introduction to the supplier diversity segment of the site. The letters show commitment from the top for these programs. The second most frequently mentioned item is certification (62.3%). Diverse suppliers cannot self-certify; they must go through the certification processes of recognized federal or private agencies, which can be rigorous and may be a hurdle for some small suppliers.

On-line applications and personnel contacts appear on more than 50% of the sites that mention supplier diversity. However, nearly half of the sites omit a contact name and request direct inquiries to an impersonal "supplier diversity office." Less than a third mention budgets or program start dates for supplier diversity initiatives. Thus the majority of firms with supplier diversity content use their public Web sites to say supplier diversity is important and direct the prospect to an agency for certification. The sites may provide a contact name and application form to begin the interaction process with the buying firm. Corporate Web sites are largely a means of expressing a commitment and initiating a review process. The Web is an innovative channel for accomplishing the initial screening of a prospective supplier and currently serves an informational purpose in relationships with supply chain members.

Rogers (1995) determined that innovators - - the earliest users, and early adopters - - the next group to begin using an innovation, make up approximately 16% of the total population of users for an innovation. These individuals or organizations serve as role models for later adopters. The 15.6% of Fortune 500 Web sites with some mention of supplier diversity are innovators and early adopters and may serve as "best practices" examples for firms that become later adopters.

CHARACTERISTICS OF HIGH ROUTINIZATION FIRMS

The top five percent of these firms in terms of Web-based supplier diversity routinization, the two "9's" and two "10's" (Table 3), are arguably a best practices benchmark by which other Web-based supplier diversity efforts can be measured. The two "10's" are Sprint (Fortune rank 81) and U.S. West (Fortune rank 134). Both are in the telecommunications industry. The two "9's" are PepsiCo (Fortune rank 76; beverages) and TRW (Fortune rank 103; motor vehicles and parts). This discussion focuses on Sprint and U.S. West.

The supplier diversity segment of Sprint's public Web site opens with a letter from the CEO about the importance of a "world class supplier base" and the role of women and minority businesses in that supplier base. They cite year-to-year increases in diversity spending as a reflection of "Sprint's company wide commitment to facilitate participation of these businesses in the purchasing process." The site provides an overview of the supplier diversity department (including names, phone numbers and e-mail addresses), its supplier database, and purchasing process. There is a list of commodities purchased. It provides a checklist for prospective suppliers, including a note about certification and an application form to be completed and submitted on-line.

U.S. West publishes a Web brochure describing its minority and women business enterprise program that includes a commitment statement from both the Chairman and President. There is a photo of the diversity program staff, a detailed statement of program accomplishments from the supplier diversity program director, and a case study of small and minority businesses that have been successful as U.S. West suppliers. The supplier diversity materials feature press releases, diversity awards, and statements from procurement officers and the vice president of supplier diversity. They provide phone numbers and addresses to certifying agencies and other diversity resources, and definitions for the categories of minority and women-owned businesses. Best practices for Web-based supplier diversity include expressed commitment, clear measures of success, contact information, and explanation of application procedures.

KEY FINDINGS

This study of Web-based supplier diversity content on Fortune 500 Web sites finds that:

few firms use the Web to describe supplier diversity programs,

firms exhibit a low degree of routinization for Web-based supplier diversity,

commitment letters, certification requirements, and electronic application forms are the most common Web-based supplier diversity content on corporate Web sites,

the degree of routinization of Web-based supplier diversity does not vary by firm size or industry,

the larger the firm, the lower the number of different types of supplier diversity comments on its site,

the larger the firm, the more likely its Web site will contain some supplier diversity content as predicted by innovation diffusion theory,

the current users of Web-based supplier diversity initiatives are innovators and early adopters as described by innovation diffusion theory, and

these early adopters provide a best-practice example for other firms that wish to encourage supplier diversity through a public Web site.

Corporate Web sites are in an early stage of adopting supplier diversity communication.

IMPLICATIONS

An implication for practitioners is that a corporate Web site can be used to identify prospective MWBE suppliers. Publishing Web-based materials relating to operational and financial requirements, and demanding external certification, assist in screening MWBE prospects. A few

firms have begun this identifying and screening process using their Web site. For researchers, this study provides a measure of Web-based content on corporate sites. This exploratory study is a starting point for examining the role of a public Web site in corporate diversity initiatives. Follow-up studies should examine the effectiveness of the Web for identifying and screening minority supplier candidates in relation to the quantity and quality of those candidates.

LIMITATIONS

A limitation of this study is that it is a point-in-time snapshot of how a group of firms are using the Web. Public Web sites change over time and so supplier diversity content may change, especially since the sites are in the early stages of supplier diversity routinization. A second limitation is the population itself; the Fortune 500 are large and not representative of every firm. However, they are likely to have the resources to support a public Web site and are also likely to have existing programs that support supplier diversity. Small-to-medium sized firms may respond differently to supplier diversity issues than the large firms that are the focus of this study. Despite these limitations, this study provides a unique view of the Web-based supply chain links that are emerging today.

CONTRIBUTION

The primary contribution of this study is to examine electronic supply chain relationships by measuring the routinization of Web-based supplier diversity initiatives. The study has both business and social implications, in addition to its role in examining an emerging usage of corporate public Web sites. A secondary contribution is to review the Web-based supplier diversity content of every Fortune 500 firm.

This study has value to practitioners such as IS managers and developers of corporate Web sites. Firms with well-established supplier diversity programs should be using the Web as a means of publicizing these programs, but most Fortune 500 firms are not utilizing a public Web site for this purpose. The drop-off in usage of the most elementary Web site application - - content publishing - - becomes more pronounced among the smaller (though still multi-billion dollar) firms on the list. The routinization measure developed in this study reveals that few Fortune 500 firms are highly routinized in using the Web to promote supplier diversity initiatives, and do not exhibit much breadth in this aspect of supply chain relationships. Given that supplier diversity is a bottom-line business issue, as discussed in the practitioner studies cited earlier, not addressing Web-based supplier diversity means that these firms are ignoring one avenue for increasing their contact with diverse customers. Thus, there are business implications for Web-based content aimed at diverse suppliers.

This study has value to researchers as well. The study applies innovation diffusion theory in a way that spans a discrete innovation (i.e., Fortune 500 Web site content relating to supply chain

interactions) and a social issue (i.e., supplier diversity). As described earlier, innovation diffusion theory has been successfully applied in both areas in a large variety of previous academic studies. The study reported in this paper is one of the few that combines both a social issue and a discrete technology innovation into a single study. This study extends prior work in the area of innovation routinization, as it moves beyond the work of researchers such as Yin (i.e., discrete administrative innovations, including computer systems), and Zmud and Apple (i.e., scanning technology used in the grocery industry), by extending routinization to a Web-based technology innovation. Finally, given the low level of adoption for the innovation being studied, this study examines the innovators, or very earliest adopters of Web-based supplier diversity content.

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APPENDIX: DATA COLLECTION FORM

Fortune 500 - Small, Minority, Women-owned, Disabled Veteran (MWBE) Suppliers

Co. Name: _____ URL: _____
Fortune Rank: _____   Industry: _____ SIC: _____

Extensiveness of Diversity Supplier Section:
_none/brief, _"call us", __ extensive; _ mention MWBE commitment, no formal site info.

Contact Name(s) YES NO E-mail link YES NO Phone #s YES NO Address YES NO
Liaison Officer Title: _____ MWBE Program/Office/Task Force YES NO
Letter from Chairman/President/CEO/COO r/e Supplier Diversity YES NO
___ definition of MW business Other: _____

Certification Programs: Required; Listed: _____ NMSDC __ WBENC __ SBA __ DOD
Provide External Links for Certification to: _____
Electronic Application: On-line Form, Adobe_____ describe formal proposal process
Application Procedures: __ D& B # ___ financials ___ sales ___ insurance certification
EDI; Bar Code; UPC; Quality conformance; price; geographic coverage; _____

Describe Supplier Development Programs:
List Reasons for Supplier Diversity Initiatives:
Other Supplier Diversity Issues:
_ program goals; _ how to submit samples; _ list MWBE awards; _ success measures

Search: minority or women-owned or small business; diversity; supplier or vendor; procurement;
no site search _____ no site index _____

UNDERSTANDING IS WORKER TURNOVER DECISIONS: IS IT JOB SATISFACTION OR JOB FIT WITH QUALITY OF LIFE GOALS?

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ABSTRACT

Over 12,000 academic and practitioner studies have been performed relating job satisfaction with voluntary turnover. However, researchers have been frustrated in explaining more than 20 percent of the variance in turnover. This paper presents the notion that traditional measures of job satisfaction may not fully capture the reason for staying or quitting. A new construct is presented that examines the congruence of fit between the job and the person's quality of life goals. By utilizing a PLS structural equation model on a sample of 135 Information Systems workers, this construct is empirically shown to be a better predictor of various measures of turnover decision (i.e., thoughts of quitting, expectation of quitting, and intention to quit) with an average explained variance of 0.50.

INTRODUCTION

The prominent paradigm in the field of voluntary turnover research is that job satisfaction is related to the decision to leave an organization. The purpose of this study is to evaluate whether or not job satisfaction is a broad enough measure of a person's overall feelings about their job or whether a new construct that measures the congruence of fit between the job and the person's goals for quality of life would be a better predictor of turnover.

Understanding the turnover decision is a relevant topic regardless of where an organization is in its business cycle. Even in times like the present when the number of Information Systems job seekers exceeds the number of open positions in the U.S., practitioners are still concerned with attracting the right people and avoiding dysfunctional turnover. Dysfunctional turnover results when the organization loses the personnel that it can least afford to lose such as those with specific skills and/or abilities (Hollenbeck & Williams, 1986). Additionally, a recent ComputerWorld job satisfaction survey of Information Systems workers (ComputerWorld 12/8/2003), determined that 42 percent of IS employees were dissatisfied with their companies. Such a large amount of dissatisfaction potentially results in increased turnover when the job market improves.

LITERATURE REVIEW

Most studies of voluntary employee turnover trace the genesis of the field to the work of March and Simon in 1958. March and Simon introduced the notion of voluntary turnover resulting from an employee's perception of ease of movement and desirability of movement. During the last four decades, job satisfaction and employee turnover have become one of the most studied topics in both academic and practitioner research with over 12,400 studies by 1991 (Hom, Griffeth & Sellaro, 1984; Hom, Caranikas-Walker, Prussia & Griffeth, 1992; Spector, 1996; Brief, 1998; Lee, Mitchell, Holtom, McDaniel, & Hill, 1999).

A significant step forward was taken when Mobley (1977) introduced the notion that turnover was actually a process. "The actual event of quitting is merely the final act following some series of mechanisms that leads to an intent and decision to resign. Thus, the sequence and duration of these mechanisms become of particular interest for the study of turnover." (Dickter, Roznowski, & Harrison, 1996). Mobley started the turnover process with job dissatisfaction being the catalyst. This catalyst then initiated thoughts about quitting and job searching, ultimately leading to an intention to quit and actually quitting. Until Mobley's work, turnover theory and research had not advanced much beyond the general framework of March and Simon (Muchinsky & Tuttle, 1979). Extensive research has followed, refining and expanding Mobley's model, but has still only resulted in explaining less than 20 percent of the variance in turnover (Healy, Lehman, & McDaniel, 1995; Mobley, Griffeth, Hand, & Meglino, 1979). Observed correlations between job dissatisfaction and turnover seldom exceed 0.40 (Hom, Griffeth, & Sellaro, 1984). In fact, in a meta-analysis of 47 studies, Carsten and Spector (1987) revealed a corrected correlation between job satisfaction and turnover of -0.26.

Job satisfaction is the extent to which an employee expresses a positive affective orientation toward his or her job (Gupta, Guimaraes, & Raghunathan, 1992). It has been measured by previous researchers either on a global or faceted basis. Tett and Meyer (1993) concluded from their meta-analysis of 155 studies "the assessment of overall satisfaction is not unduly compromised by the use of facet-based scales" (pg. 281). In other words, there is no difference in the predictive power of models using either the global or faceted measurement approaches. Thus, this study employs a global measure of job satisfaction.

Global measures of satisfaction are typically worded as "All in all, how satisfied would you say you are with your job" (McFarlin & Sweeney, 1992). Although the questions ask about the "job", the position of this paper is that there is room for interpretation as to how the respondent might consider this question. Do respondents answer it by focusing only on the job itself or are they also thinking of the job fit in terms of its' broader impact on his/her life? Perhaps traditional research focusing on job satisfaction is missing the true beliefs that make an employee begin having thoughts about quitting. The defining example is the schoolteacher who dislikes her job but does not intend to quit because the work hours satisfy her family needs. This person would answer a

survey saying that they were dissatisfied with their job, but did not intend to quit - a possible anomaly for an empirical research project.

To answer this question, a new construct is introduced as an alternative to job satisfaction for predicting turnover. This construct evaluates the quitting process as a result of a failure of the job to fit with the quality of life goals the employee has for him or herself. In considering quality of life, George and Jones (1996) noted that "Well-being in life has three complimentary aspects of well being: value attainment (e.g., how one's life is evaluated relative to one or more standards or values such as virtue or success); life satisfaction (the extent to which one is satisfied with one's life or has come to evaluate one's life in positive terms); and the extent to which a person experiences positive feelings or moods" (pg. 318). Brief (1998) described terminal needs in life as professional, social, and personal. Professional goals include professional growth or advancement and status within the community. Social goals include needs for recreation and social relationships. Personal goals are financial, work/family life balance, and spiritual/ethical goals. In this research, measures were developed to tap into these facets of the congruence of fit of the job to the professional, social, and personal goals as well as to overall quality of life goals. Measures to reflect this construct (Table 1) had to be developed because no empirically validated measures were available.

Table 1. Questions Used to Measure Fit of Job to Quality of Life Goals *		
CONSTRUCT	SUB COMPONENT	MEASURES
Global		1 Overall, my job is aligned with the quality of life goals I have set for myself 2 In general, my job fits with my overall goals in life
Professional	Growth & Advancement	1 My job fits the goals I have for professional growth 2 My job aligns with my goals for professional advancement
Professional	Status	1 My job fits the goals I have for status within the community 2 My job is consistent with the level of community status I seek
Social	Recreational	1 My job fits my needs for recreational opportunities 2 My job aligns properly with my needs for recreation
Social	Relationships	1 My job fits my goals for social relationships 2 My job is consistent with my social relationships
Personal	Financial	1 My job aligns with my goals for financial accomplishment 2 My job properly fits with my financial objectives
Personal	Work/Family Balance	1 My job fits my goals for work/family life balance 2 My job aligns with the work/family life balance I seek
Personal	Spiritual/Ethical	1 My job is consistent with my spiritual/ethical goals 2 My job aligns with my spiritual/ethical goals
* 7 pt scale Likert scale from -3 to +3 (strongly disagree, disagree, somewhat disagree, neither agree or disagree, somewhat agree, agree, strongly agree)		

In order to evaluate this new construct against the traditional job satisfaction measures, an empirical study was designed that would gather both job satisfaction and congruence of fit data coupled with 3 representative turnover decision constructs used in turnover literature. By triangulating the predictive power across three different dependent variables, a better understanding of the relative strengths of these antecedents in predicting voluntary turnover can be determined. While, for many, the preferred dependent variable might be actual turnover behavior, that data was not available at the time and therefore surrogate turnover decision variables were used. Specifically, thoughts about quitting, the expectation of quitting, and the formation of the intention to quit were used as surrogates or immediate antecedents to the actual turnover behavior. According to Dalton, Johnson, and Daily (1999), "The key issue with regard to the appropriate use of a surrogate variable, however, is its relationship to the actual variable. The usual assumption is that the surrogate variable is highly correlated with its actual behavioral counterpart" (p. 1338).

The validity of the relationship between intention and behavior has been established in a number of different studies. A series of meta-analysis (Steel & Ovalle, 1984; Hom et al., 1992; Tett & Meyer, 1993) have reported weighted average correlations between intention to quit and turnover behavior of 0.50, 0.36, and 0.52 respectively. The genesis of this well-correlated relationship can be traced back to Ajzen and Fishbein's theory of reasoned action which says "according to the theory of reasoned action, attitudes follow reasonably from the beliefs people hold about the object of the attitudes, just as intentions and actions follow reasonably from attitudes" (Ajzen, 1988, p.32). A number of turnover studies have used this approach with success (Joy, 1989; Doran, Stone, Brief & George, 1991; Sager & Menon, 1994; Igbaria & Greenhaus, 1992; Sager, Griffeth & Hom, 1998; Dalton, Johnson & Daily, 1999; Vandenberg & Nelson, 1999). Moreover, beyond behavioral turnover, these decision constructs can also be argued as potentially predictive of an employee's level of productivity, quality of work, or other withdrawal behaviors.

THE STUDY

A questionnaire was administered to 150 information systems workers in an independent school district. There were 135 usable responses representing a 90 percent response rate. The instrument included the measures of congruence of fit listed in Table 1 along with global measures of job satisfaction adopted from previous research as listed below:

1.   All in all, how satisfied would you say you are with your job?
2.   How would you rate your satisfaction with your job?
3.   Overall, I am quite pleased with my job

Responses were given on a 7-point Likert scale and analyzed using the structural equation modeling software PLS Graph version 3.0 (build 1060). Our model, as shown in Figure 1, uses both job satisfaction and congruence of fit to predict each of the three turnover decision constructs of

thoughts about quitting, expectation of quitting, and intention to quit. In addition, model runs were made where only one exogenous construct (either congruence of fit or job satisfaction) was used to predict each turnover decision. These nine analyses using three dependent variables provide multiple criterion validity to the research.

Figure 1: Theoretical Model
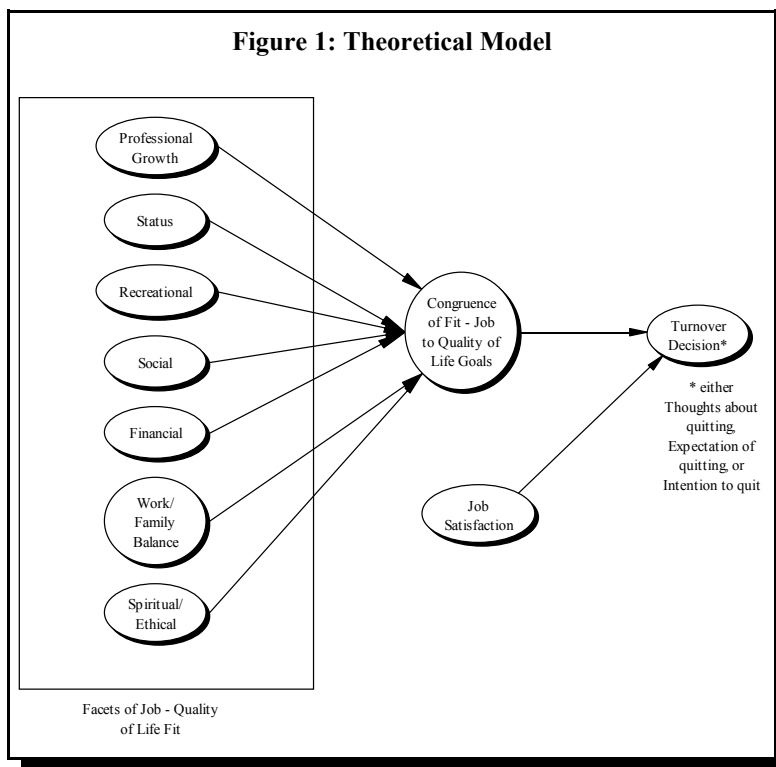
Measurement Model

The results of our analyses of the measurement model show an excellent fit to the constructs. This conclusion begins by examining the loadings of the individual reflective measures to their respective construct. According to Chin (1998) loadings should be 0.70 or higher, although loadings over 0.60 and even 0.50 can be acceptable if there are sufficient good measures reflecting the same construct. All factor loadings were in excess of .90.

The second and more detailed test of measurement model validity is to see how each item relates to other constructs. Not only should each measure be strongly related to the construct it attempts to measure, but it should not have a stronger connection with another construct. Otherwise, such a situation would imply that the measure in question is unable to discriminate as to whether it belongs to the construct it was intended to measure or to another (i.e., discriminant validity problem). Table 2 provides the correlations of each item to its intended construct (i.e., loadings) and

to all other constructs (i.e., cross loadings). As Chin (1998) notes, going down a particular construct column, you should expect to see item loadings to be higher than the cross loadings. Similarly, if you scan across a particular item row, you should expect to see that item be more strongly related to its construct column than any other construct column. This was indeed the case. The items exhibit discriminant validity by loading more highly on their own construct than on other constructs and that all constructs share more variance with their measures than with other constructs.

	Intention to Quit	Global Fit	Growth	Spiritual	Work/ Family Balance	Financial	Social	Global Satisfaction	Thoughts Quit	Expect Quit	Status	Recreation
								Table 2. Measure Cross Loadings				
Q5.06	**0.9853**	-0.6673	-0.6211	-0.4374	-0.2883	-0.5623	-0.4183	-0.6053	0.7508	0.8870	-0.5943	-0.1603
Q5.12	**0.9851**	-0.7297	-0.6637	-0.4543	-0.2517	-0.6053	-0.4083	-0.6517	0.6956	0.8646	-0.6317	-0.1534
Q1.08	-0.6533	**0.9613**	0.8400	0.7574	0.6415	0.7245	0.6305	0.7251	-0.6383	-0.6362	0.8275	0.4636
Q1.16	-0.7107	**0.9646**	0.8729	0.6742	0.4437	0.7458	0.6243	0.8407	-0.6772	-0.6917	0.7949	0.2260
Q1.01	-0.6638	0.8292	**0.9525**	0.6194	0.4924	0.5939	0.6103	0.6383	-0.5313	-0.6435	0.6970	0.2866
Q1.09	-0.5831	0.8689	**0.9568**	0.5984	0.4091	0.7159	0.4683	0.6786	-0.5584	-0.5730	0.7940	0.2545
Q1.07	-0.3538	0.6707	0.5356	**0.9625**	0.5532	0.5574	0.4709	0.4988	-0.4503	-0.5340	0.6020	0.4914
Q1.15	-0.5116	0.7594	0.6878	**0.9708**	0.6352	0.6630	0.4785	0.5662	-0.4684	-0.5983	0.7272	0.4513
Q1.06	-0.2861	0.4671	0.3744	0.4681	**0.9397**	0.3278	0.4230	0.3837	-0.3706	-0.3365	0.5598	0.5784
Q1.14	-0.2412	0.5879	0.5077	0.6828	**0.9624**	0.3969	0.5956	0.4390	-0.3541	-0.3703	0.5367	0.6725
Q1.05	-0.5480	0.7467	0.6737	0.5705	0.3387	**0.9663**	0.3621	0.6784	-0.4838	-0.5147	0.7358	0.2797
Q1.13	-0.5966	0.7275	0.6535	0.6557	0.4048	**0.9645**	0.4534	0.6613	-0.6285	-0.6288	0.7364	0.3726
Q1.04	-0.3135	0.5832	0.4647	0.4105	0.4895	0.3912	**0.9492**	0.6965	-0.4908	-0.3838	0.4846	0.4213
Q1.12	-0.4781	0.6567	0.6027	0.5211	0.5483	0.4130	**0.9601**	0.6352	-0.6090	-0.5597	0.5438	0.5492
Q3.01	-0.6688	0.8173	0.7016	0.5724	0.4506	0.6879	0.7032	**0.9603**	-0.6569	-0.6633	0.7048	0.2291
Q3.02	-0.5913	0.7811	0.6723	0.5481	0.4168	0.6758	0.6730	**0.9864**	-0.5662	-0.5940	0.7310	0.2701
Q3.03	-0.5952	0.7756	0.6375	0.4896	0.3999	0.6609	0.6504	**0.9752**	-0.5800	-0.5886	0.7081	0.2583
Q5.01	0.6238	-0.6235	-0.4696	-0.4757	-0.3210	-0.5137	-0.4597	-0.4823	**0.9190**	0.6546	-0.5466	-0.3720
Q5.15	0.7338	-0.6458	-0.5843	-0.4130	-0.3806	-0.5529	-0.6076	-0.6590	**0.9391**	0.7729	-0.6353	-0.2220
Q5.05	0.7813	-0.6038	-0.5780	-0.5606	-0.4528	-0.5560	-0.4029	-0.5754	0.6448	**0.9308**	-0.5644	-0.3386
Q5.16	0.8842	-0.6886	-0.6167	-0.5468	-0.2648	-0.5574	-0.5274	-0.6159	0.7966	**0.9504**	-0.6030	-0.2991
Q1.02	-0.6506	0.8247	0.7843	0.7129	0.5617	0.6862	0.6230	0.7656	-0.6186	-0.6662	**0.9346**	0.4481
Q1.10	-0.4911	0.7278	0.6552	0.5571	0.4973	0.7276	0.3607	0.5808	-0.5603	-0.4725	**0.9152**	0.3329
Q1.03	-0.1419	0.2737	0.1954	0.3446	0.6112	0.2277	0.5183	0.2605	-0.2713	-0.3193	0.3422	**0.9204**
Q1.11	-0.1562	0.3795	0.3184	0.5407	0.6344	0.3832	0.4575	0.2313	-0.3139	-0.3168	0.4444	**0.9594**

Structural Model

The structural model reflects the hypothesized linkages between the constructs and defines the strength of the various causal relationships. The test of validity of the structural model can be accomplished by first, determining the amount of variance explained in the dependent constructs

and second, by examining the paths among the latent variables to determine the statistical significance of each of the causal relationships.

The variance explained is a measure of the predictive power of the model and is reflected by the R-square values. Table 3 lists the R-square values computed for each of the nine analyses and shows that our model has very high predictive power. As was mentioned earlier, previous research has traditionally explained no more than 20 percent of the variance in turnover

In addition, Table 3 provides the relative impact of our constructs. When job satisfaction and congruence of fit are run individually, each produces a relatively high path coefficient suggesting that each of these constructs can represent a good predictor of the quitting thoughts, expectations, and intentions. However, when evaluated together the congruence of fit becomes the dominant factor and reduces job satisfaction to being statistically non-significant for two of the turnover decisions (thoughts about quitting and intention to quit). In the case of expectation to quit, congruence of fit was more than twice as important.

Table 3. Structural Model Results				
Endogenous Variable	Exogenous Variable	R-square of Endogenous Variable	Path Coefficient (Satisfaction)	Path Coefficient (Fit)
Thoughts about Quitting	Satisfaction only	0.3940	0.6280	
	Congruence of fit only	0.4660		0.6830
	Both	0.4780	n.s.	0.5320
Expectation of Quitting	Satisfaction only	0.4010	0.6330	
	Congruence of fit only	0.4750		0.6890
	Both	0.4900	0.2160	0.5130
Intention to Quit	Satisfaction only	0.4080	0.6380	
	Congruence of fit only	0.5050		0.7100
	Both	0.5150	n.s.	0.5650
n.s. = not statistically significant obtained via 500 bootstrap resamples				

Although secondary to this study, Table 4 provides information on the relative impact of the congruence of fit facets to overall job fit. These facets can be used to determine which sub areas of job-to-quality of life fit are most important in producing an overall feeling of fit for our IS worker sample. The overall R-square of 0.897 indicates that we've obtained a relatively comprehensive set of facets. Moreover, we find that fit to professional growth and advancement had more than twice the impact than any of the other facets.

Table 4. Relative Impacts of Facets to Overall Congruence of Fit (overall R-square 0.897).		
CONSTRUCT	SUB COMPONENT	Standardized PLS path estimate
Professional	Growth & Advancement	0.429
Professional	Status	0.178
Social	Recreational	0.118
Social	Relationships	0.187
Personal	Financial	0.162
Personal	Work/Family Balance	n.s.
Personal	Spiritual/Ethical	0.167
n.s. = not statistically significant obtained via 500 bootstrap resamples		

DISCUSSION

A student recently said, "My Dad hated his job, but he worked at it for 20 years so that he could put my sister and I through college." The Dad hated the attributes of the job, but stayed with it because it fulfilled a quality of life goal to attain a certain level of financial well being. In response to a job satisfaction survey, the Dad would answer that he was dissatisfied with his job, but had no intentions of quitting. This dichotomy may represent a statistical confound for the traditional job satisfaction-to-turnover models. It was therefore posited that measures of job satisfaction do not necessarily reflect the congruence of fit with overall quality of life goals and thus a new measure could improve the prediction power of a voluntary turnover model.

Our research question thus became: "Do some people look at their jobs in a broader context than just the attributes of the job itself?" In other words if a person is asked about their level of satisfaction with their job, can they differentiate the job itself from its overall influences on the quality of life. Our belief is that not all people are answering these questions in a consistent manner. Some respondents see job satisfaction as it relates strictly to the job itself and others see job satisfaction as the job relates to the quality of life. The lesson for the researcher is that this dichotomy may exist and in order to improve the results of models using the job satisfaction construct, specific instructions should be given to the respondent as to how that question should be evaluated.

On the other hand, the congruence of fit between quality of life goals and the job, with the associated measures used in this study, would appear to be a superior yardstick for future research. This construct eliminates the definitional problems associated with job satisfaction measures and represents a new point of departure from previous studies. Nonetheless, some limitations of this study should be noted. First, the sample size is somewhat limited. That was one of the reasons for using PLS rather than covariance-based methods such as LISREL, EQS, or AMOS. PLS can often

produce valid results even under conditions of smaller sample sizes (Chin, 1998; Chin & Newsted, 1999). Minimal recommendations for sample size using PLS range from 30 to 100 cases; while covariance-based methods generally require 200 to 800.

Second, the generalizability of the results could be questioned. The respondents in this study were information systems workers in a school district. The preponderance of them were para-professional help desk people assigned to the individual schools to assist with teacher problems. Therefore, this sample does not generalize to the normal skill mix typically found within the Information Systems department of other businesses. However, despite these limitations the study provides compelling evidence for future work to both validate these findings and gain further insight into the turnover process.

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THE CASE FOR MEASURING SUPPLIER SATISFACTION

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ABSTRACT

Many organizations struggle in their efforts to establish supplier partnerships, and many such partnerships fail to live up to their potential. This paper examines why partnerships do not deliver the hoped for results, and proposes supplier satisfaction surveys as a possible remedy to this situation. Drawing upon empirical studies in the supply chain management literature, the paper establishes that (i) successful partnerships require trust to develop between organizations; (ii) such trust requires open, two-way communication; and (iii) despite the recognition of the importance of communication, a significant and persistent perception gap exists between buyers and suppliers within many such partnerships. The cause of this perception gap is then traced to a communication imbalance between buyers and suppliers. While buyers generally communicate expectations and provide feedback to suppliers, there is little evidence that expectations and feedback flow the other direction (i.e., from suppliers to buyers). The paper makes the case that buyers can use supplier satisfaction surveys to correct this imbalance and eliminate the perception gap impeding the development of effective buyer-supplier partnerships.

INTRODUCTION

Supply chain management theory and practice has evolved over the last twenty years from a focus on transaction processes based on arms-length agreements with suppliers to a focus on collaborative processes based on mutual trust and information sharing (Ghosal & Moran, 1996; Hoyt & Huq, 2000). Organizations are increasingly trying to work much more closely with their suppliers to try to optimize the performance of their supply chain, and many of these organizations now describe their relationship with their suppliers as partnerships. Research indicates that when well executed, these collaborative, partnership-like relationships with suppliers can lead to improved firm performance (Tracey & Vonderembse, 2000; Jones et al., 1997; Liedtka, 1996; Handfield & Nichols, 1999).

For these types of collaborative partnerships to be successful, however, buying organizations must implement fairly radical changes to their own organizational processes and structures to support them (Liedtka, 1996; Mariotti, 1999). Further, the processes and methods needed to really achieve such partnerships are still being developed, understood and refined. As a result, many organizations struggle in their effort to implement partnerships (Mariotti, 1999; Spekman et al.,

1998). Many buyer-supplier partnerships do not live up to their potential, and many are not true "partnerships" in any real sense of that term.

Saying one has partnerships with their suppliers is quite easy, but actually transforming one's approach to how one works with and manages their suppliers to achieve real partnerships with one's suppliers is significantly more complex. As Spekman et al. (1998) characterize it, most organizations that claim to have partnerships with their suppliers have simply achieved some level of cooperation whereby the firms "exchange bits of essential information and engage some suppliers/customers in longer-term contracts" (p. 55). True partnerships, however, are built on a foundation of trust and commitment that goes well beyond mere cooperation. Partners collaborate with each other to develop shared goals and to integrate their processes into their major customers' processes. Such firms recognize and act on the fact that their long-term success is dependent on their weakest supply chain partner. Many companies, however, never reach this stage of true partnership and collaboration (Spekman et al., 1998).

This paper proposes a means to help move organizations toward true partnerships with their suppliers – supplier satisfaction measurement. It proposes that buyers need to think of their suppliers more like they think about their customers, and only when this occurs will organizations really begin to view their suppliers more like partners and less like traditional suppliers. The paper begins with a look at the prerequisites of successful partnerships – inter-organizational trust and communication. After establishing the role of trust and communication, the paper focuses on the significant gap that exists between buyers and their suppliers regarding their expectations and assessments of performance in buyer-supplier partnerships. This gap creates a significant barrier to the development of trust in the relationship. It is then proposes that measuring suppliers' expectations and perceptions regarding their relationship with buying organizations is the simplest way to overcome this perception gap and move the relationship closer toward a true partnership. Finally, it is proposed that the underlying cause of the perception gap relates to the highly directional view that most organizations hold relative to their supplier chains, and that in reality buying organizations should view their suppliers in a similar way that they view their immediate customers in the supply chain.

SUCCESSFUL PARTNERSHIPS ARE BUILT ON COMMUNICATION & TRUST

Many theorists propose, and empirical studies seem to confirm, that success of supplier partnerships depend, at least in part, upon the level of trust and cooperation that can be achieved between the organizations and upon the extent and quality of information sharing that occurs between the organizations. Ellram (1995) collected data from 80 matched pairs of buyers and supplier organizations in order to assess what factors led to successful partnerships. Ellram found that for both buyers and suppliers, that communication, trust, strategic direction and shared goals were the critical factors in creating and maintaining successful supplier partnerships. Monczka et al. (1998) found similar results by looking at survey data from 84 buying organizations. Monczka

et al. measured partnership success in terms of the buying company's satisfaction with the partnership, the performance improvement experienced by the buying company as a result of the partnership, and the extent to which the partners were able to work together (e.g., how flexible the partners were to requests made by the other and whether partners met their commitments within the partnership). The researchers found that trust, interdependence, information quality, information sharing, information participation (i.e., the extent to which partners engage in joint planning & goal setting activities) and joint problem solving efforts all contributed to more successful supplier partnerships.

Krause and Ellram (1997) collected data from 520 buying organizations in order to investigate the related issue of supplier development efforts. Using a split sample approach, they found that the organization's that were satisfied with the results of their supplier development efforts tended to take a more proactive approach to supplier performance (e.g., trying to anticipate supplier performance problems and viewing suppliers as extensions of their own organization), put more effort and resources into their supplier development efforts (e.g., supplier evaluation & feedback, training of supplier personnel, and recognition of outstanding suppliers), and exhibited greater willingness to share information with their suppliers. While this last study focused on supplier development as opposed to supplier partnerships, it is relevant here given many organizations efforts to form supplier partnerships have roots in their efforts at supplier development.

Repeatedly, then, large sample studies have found that communication and trust play a pivotal role in the establishment of partnership relationships between buyers and suppliers. Other researchers (e.g., Henriott, 1999; Mariotti, 1999; Yuva, 2001) have also argued that the information sharing is really a prerequisite for the development of trust, and subsequent studies focused on trust between buying and supplying organizations confirm the importance of communication to the development of trust and relationship quality. Parsons (2002), for example, investigated the determinants of buyer-supplier relationship quality, measuring relationship quality as the buying organizations' assessment of the trust that existed within the relationship in addition to the buying organizations' general level of satisfaction with the relationship. Based on survey results from 368 organizations, Parsons found that both the interpersonal relationships between the individual buyers and salespeople and the relationship between the companies in terms of the existence of mutual commitment, goals and relationship benefits contributed to higher relationship quality. Communication plays a significant role in both the interpersonal relationships as well as in the organizations identifying and developing mutual goals and commitment.

In another study looking at trust in buyer-supplier relationships, Cousins & Stanwix (2001) looked at the management of supplier relationships among automobile manufacturers operating in the U.K. in an effort to identify those factors that contributed to a high trust relationship. Results indicated that manufacturers found 17 factors contributed to high trust relationships, including full and open communication, consistency from all personnel, full cost transparency, receptiveness to supplier ideas, and providing help to suppliers with 'no strings attached'. Interestingly, the Japanese vehicle manufacturers in the study reported that these contributing factors were fairly easy to

implement, while non-Japanese manufacturers found such activities to be harder to implement. The authors of the study concluded that the Japanese vehicle manufacturers tended to view 'relationship development' as what supply chain management was all about – it was simply an integrated part of what they did. Non-Japanese vehicle manufacturers, on the other hand, seemed to think more in terms of 'supplier development' rather than 'relationship development' and viewed supplier development as an extra responsibility of their work (as opposed to an integrated part of it).

Cousins & Stanwix's finding that many organizations fail to view the relationship development component as central to the supply chain management function is consistent with the more general finding that buying organizations struggle to achieve true partnerships with their suppliers and that many continue to manage suppliers based on more of an arms-length relationship approach (Maniotti, 1999). It is also consistent with the findings of Spekman et al. (1998), who studied the practices of buyers and sellers in 22 aggregate supply chains, and found that "buyers tend to embrace the notions of collaboration less than sellers and appear to fear the close ties that are required for integrated supply chain management" (p 59). For example, Spekman et al. found that buyers were less willing to devote extra effort to their supply chain relationships and were less likely to view their suppliers as irreplaceable and essential to their business than their immediate customers in the supply chain. So while communication and trust seem to be part of the foundation upon which supplier partnerships are built, the evidence suggests that many organizations struggle to really achieve these goals. This difficulty in achieving trust appears to be based in part on the fact that buyers and suppliers perceptions of their partnership arrangements differ significantly.

BUYERS AND SUPPLIERS DO NOT PERCEIVE PARTNERSHIPS THE SAME

Ellram (1995) and Blancero and Ellram (1997) carried out one of the first supplier partnership studies dealing with the perceptions of both buyers and suppliers. Ellram and Blancero used data collected from 80 matched pairs of buyers and their corresponding suppliers to compare the perceptions of buyers and suppliers in terms of which factors were the most important contributors to successful supplier partnerships (Ellram, 1995) and in terms of what was happening in these relationships (Blancero & Ellram, 1997). In terms of factors contributing to a successful partnership, both buyers and suppliers agreed that communication and trust were critical. Suppliers, however, consistently saw the relationship aspects of the partnership (e.g., relationships among top management teams, the existence of multiple relationships between the organizations, the personal relationship between the buyer and salesperson) as more significant to the success of the partnership than did the buying organization. In terms of what was happening in these relationships, buyers and suppliers frequently did not share the same perceptions. Further, where there were differences in perceptions, the buying organization in every case perceived that their own behavior was more supportive of the relationship than the suppliers perceived their behavior. The buying organization perceived that they met with the suppliers top management more, that they more regularly communicated forecasts, production schedules and proprietary information, that they worked more

with suppliers on cost reduction and quality improvement efforts, and that they involved suppliers early in the design process more than suppliers perceived these activities occurring.

Subsequent studies investigating the perceptions of both the buying and supplying organization confirm Ellram (1995) and Blancero and Ellram's (1997) finding that perceptions between buyers and suppliers differ. Campbell (1997), for example, conducted a study in the European packaging industry, collecting data on the relationship between 45 buying organizations working with three large packaging suppliers. Data was collected from 28 salespeople from the three suppliers and 114 purchasing agents from the 45 buying organizations. Campbell found that the buyer and salesperson shared the same expectations about the partnership in only 42 of the 114 relationships (37%). Further, no correlation was found between a buyer's trust in the supplier and the corresponding supplier's trust in the buyer, nor did the suppliers' perceptions of the extent of proprietary information disclosed by the buying organization match the buying organizations perceptions on the extent of proprietary information disclosed. In another study of a Korean semiconductor manufacturer and its key suppliers, Kim et al. (1999) found significant perception gaps existed between buyer and suppliers. Like Ellram's (1995) study, Kim found that suppliers perceived relational characteristics like communication, familiarity and long-term goals to be more important to the effectiveness and success of the relationship than did the buying firms. Further, Kim found that this perception gap had a negative impact on inter-firm trust.

In fact, no studies could be found that indicated that buyers and suppliers consistently shared the same perceptions regarding their expectations for and/or the subsequent behaviors realized in buyer-supplier partnerships. The evidence suggests that the vast majority of buyers do not have an accurate picture of their suppliers' perceptions of the partnership – either in terms of expectations or performance. It is difficult to understand how an organization can truly claim to have a partnership with suppliers when such a situation exists. Rather, the ongoing perception gap would appear to provide a plausible explanation for why so many organizations do not realize the full potential from their partnerships.

Wagner, Macbeth and Boddy's (2002) in-depth case study on the relationship between a buying organization and one of its suppliers that it was attempting to develop a partnership relationship with provides a good example of what can happen when organizational perspectives on the relationship differ. In early stages of the partnering process, the supplier felt a continuing and significant imbalance of power in favor of the buying organization. Among the supplier's personnel, this created the impression that improvement ideas would only be considered and accepted by the buying organization if there was minimal impact and disruption for the buying organization. Whether or not this perception was justified was unclear to the researchers, but what was clear was that it greatly limited the range of ideas put forth by the supplier. As trust and commitment grew, and as the buying organization moved more toward treating its supplier more like a partner and less like a traditional supplier, the supplier became more comfortable communicating to the buying organization things that the buying organization could be doing differently to help the supplier.

THE ROOT CAUSE OF THE PERCEPTION GAP: ONE DIRECTIONAL THINKING

This paper has established three facts so far about the current state of buyer-supplier relationships based on the supply chain management literature. First, buying organizations increasingly face the competitive need to establish partnership-like relationships with their suppliers in an attempt to optimize performance of the value chain for their end customers. Second, communication and the establishment of trust between buying organizations and their suppliers are consistently found to be key components to the establishment of successful partnerships. Finally, there is strong evidence that a perception gaps exits between buying organizations and their suppliers; despite the recognition of the importance of communication in such efforts, most organizations' communication efforts seem to fail. Such differing perceptions are likely to generate underlying conflict in these relationships and impede the development of trust, which is so critical to the success of such partnerships. As such, buying organizations and suppliers attempting to establish or maintain partnership-like relationships need to find a way to overcome this perception gap in order to advance the relationships toward true partnerships where they can produce maximum operational and strategic benefit to the firms.

Before discussing the proposed solution to this perception gap, it is worth considering the underlying cause of this perception gap. The cause would seem to relate to the fact that information sharing in most buyer-supplier arrangements, even many of those that the buying organization calls partnerships, is limited and somewhat one dimensional, focusing primarily on the performance of the supplier (Campbell, 1997). Buying organizations now routinely communicate detailed expectations to their suppliers - both specific expectations (e.g., we want our supplier to perform this service, and this is how we want it performed) and general expectations (e.g., we expect suppliers to be proactive in working with our company). Buying organizations are also increasingly providing their suppliers with regular, detailed feedback on how the suppliers are meeting these expectations. But there is little evidence that buying organizations are asking for, or are typically receiving, the reverse information. That is, buying organizations are not in general, asking their suppliers what their suppliers expect from them, nor are they typically asking their suppliers for feedback on how they, the buying organizations, are performing. This limited view that most buying organizations take to information sharing, amounting really to information giving, appears to create the perception gaps revealed in the literature and hinders many of these arrangements from developing into true partnerships that lead to improved firm performance.

This one directional flow of information appears to be symptomatic of a broader, entrenched view that supply chains have an inherent directional focus to them. That is, when organizations think about their supply chains, they think first about the flow of goods and services from raw material supplier toward end customer (i.e., constantly moving downstream) and second about the flow of information in the supply chain from end customer backward toward raw material supplier (i.e., constantly moving upstream). There is also a power component to this linear thinking, whereby organizations downstream tend to have more power, while organizations upstream have

less power based on the fact that customers have the power to "choose" a different supplier, while suppliers are not in the same position of simply being able to "choose" a different customer.

As a result of this linear thinking, organizations tend to treat downstream members of the supply chain very differently than they do upstream members of the supply chain. Organizations will do whatever it takes to be the preferred supplier of their immediate customer, but rarely will they approach their upstream suppliers with the attitude of doing whatever it takes to be their suppliers' preferred customer. In fact, more typically, organizations expect their suppliers to do whatever it takes to be their preferred supplier. This fails to optimize the performance of the supply chain, however, because each upstream member of the chain must work within the constraints, both explicitly stated by the downstream member and perceived by the upstream organization, and optimize within these set of constraints. True optimization of the supply chain requires these constraints to be examined and in many cases modified through collaboration among the upstream and downstream members of the supply chain.

What is needed is for organizations to see beyond the directional orientation that they have toward their supply chains. A significant advancement in the supply chain management literature along these lines is the use of the term "networks" – either described as supply networks or demand networks. Being a member of a demand network implies much less directionality to relationships than does a supply chain. Ultimately, competition is between these networks of companies working together to satisfy the final customer, not between individual companies. That is, the competitive success of an individual firm has as much to do with what its partners do as it does with what it does. If an important partner in such a network fails to perform its function well, the whole network of organizations suffers because end customers switch to an alternative network of companies to purchase from. Further, it largely doesn't matter whether that organization that fails to perform is an upstream or downstream organization, the network itself suffers as a result. Given this state of competition, firms need to be working more to insure that their actions support the actions of all members of the network, regardless of whether they are upstream or downstream. It is suggested that firms take what they know about serving downstream organizations, and apply that to better serving upstream organizations.

THE SOLUTION: MEASURING SUPPLIER SATISFACTION

The simplest solution to insuring that differences in perceptions between buyers and suppliers doesn't restrict the gains from supplier partnerships is for buyers to measure supplier perceptions and determine their expectations for the partnership, their expectations of the buyer in the partnership, and their perceptions of the buyer's performance in the partnership. In essence, buyers need to measure supplier satisfaction in the same way that their firm would measure customer satisfaction. Such measurement would allow firms to begin to bridge the perception gap in their relationships with suppliers, allowing relationships to advance toward true collaboration and

partnership. With a more accurate understanding of its role in the partnership, the buying firm is then in a position to change its behaviors to better allow the supplier to meet the buying firm's needs.

Roberts (2001) has recently proposed that supply chain management/purchasing departments should begin to survey their internal customers – the marketing, production and engineering functions within the firm – as a basis for evaluating and improving its performance. Roberts suggests that surveying internal customers will help purchasing managers better understand their customers and their customers to better understand them. It also signals to internal customers that the purchasing group cares about their needs and as such helps promote trust between the purchasing group and its customers. Communication of survey results back to respondents, along with action plans for improvements based off the surveys, represents an opportunity to further develop trust and enhance the relationship with internal customers. Such communication shows internal customers that the purchasing group is responsive to their concerns and needs. What is suggested in this paper is that this approach be extended to the organization's suppliers, since the same need for trust and a working relationship exists. Roberts proposes such a survey because the purchasing department serves these other departments in the firm. In the similar way, the purchasing group provides a service to the supplier. That is, one role of the purchasing department is to facilitate the interactions between suppliers and the rest of the organization. It would make sense for the purchasing department to ask how well it was meeting both sides' needs in this role. The survey proposed in this paper, however, would go beyond simply measuring supplier satisfaction with the purchasing department (although a more limited survey like this might provide a good starting point) and also look at the suppliers' satisfaction with the overall performance of the firm.

Measuring suppliers' expectations of the buying organization and suppliers' perceptions of the buying organization's performance represents a very concrete process aimed at maintaining and strengthening partnerships with suppliers. Landeros et al. (1995) found that many buyer-supplier partnerships fail because partners lack an established process to maintain the relationship. The researchers argued that an important part of such a maintenance process was to be able to understand how problems can enter a relationship. Further, Landeros et al. found that differences between expectations & performance, more than absolute performance, drove successful buyer-suppler relationships. According to Landeros et al. (1995, p. 10), "The partners expectations and perceptions of each other's performance generally appear to be the primary factors in the development and maintenance of a sound buyer-seller partnership." Given the importance of both expectations and perceptions of performance, a servqual-like instrument might be an appropriate starting point for developing an appropriate survey. This is also the type of survey methodology that Roberts suggested was needed when working with internal customers. Interestingly, while Landeros et al. (1995) argued that successful buyer-supplier relationships depended on the fulfillment of mutual expectations, their recommendation focused solely on the buyer developing expectations for the supplier and measuring the supplier's performance against those expectations, and did not deal at all with creating expectations for the buying organization or measuring the buying organization's performance relative to those expectations.

Approaches other than a formal supplier satisfaction survey might also be used to evaluate the buying organization's performance vis-à-vis its suppliers – the point is more generally that buying organizations need to get feedback from their suppliers on how well they believe that the buying organizations are performing in the relationship. Vokurka (1998), for example, describes one company's successful supplier partnership program that included a supplier advisory council that was initiated to create a mechanism to foster continuous improvement in how the company managed supplier partnerships. The council consisted of either the president or division head of six major material suppliers along with the company's own president and its directors of manufacturing, engineering and purchasing. The council's purpose was "to review current and proposed purchasing policies and practices with the overall goal of making the company the best customer it can be." (Vokurka, p. 33). Most organizations do not approach their relationship with suppliers with the goal of being the best customer possible. However, it is this underlying change in attitude that is necessary to truly optimize performance in the supply chain.

CONCLUSIONS

This paper has attempted to make the case that buying organizations should be treating suppliers more like customers and specifically need to begin to seek supplier feedback on the buying organization's performance. Empirical evidence clearly indicates that (i) buying organizations are attempting to establish more partnership like relationships with their suppliers, and that when successfully implemented, such relationships lead to improved firm performance and competitive standing; (ii) successful partnerships require trust to develop between organizations, and such trust requires open, two-way communication; and (iii) despite traditional communication efforts between buyers and suppliers, a significant and persistent gap exists between buying organizations and their suppliers in terms of their expectations and their perceptions of the their partners performance.

These three results, taken together, indicate a significant shortcoming in the management of an organization's supply chain. It is proposed that the root cause of this problem stems from thinking about supply chains as having a dominant directional component. Treating suppliers a little more like customers should help to overcome this mentality, allow firms to eliminate the significant perception gap that impedes development of a true partnership approach, and promote real optimization of performance across an organizations supply chain. The proposed first step is for buying organizations to ask their suppliers for feedback on how well they are performing in the relationship. This information should put buyers in a much better position to truly optimize performance of the supply chain.

It could be argued that the analysis and proposals put forth in the latter half of this paper are off the mark because suppliers are different from customers and can generally be replaced more easily than customers (assuming that another supplier exists that has the necessary capacity and capabilities to meet the buyer's needs). This argument, however, misses the point. Organizations that think about their suppliers as easy to replace are almost certainly not treating their suppliers like

partners. The point is that organizations need to begin to view their key suppliers as invaluable as their key customers, and begin to treat them as such. Measuring suppliers' satisfaction with the buying organization's performance and responding to supplier concerns raised through such a process strengthens the network of companies that the buying organization competes within, ultimately benefiting the buying organization.

In closing, it should be noted that thinking about suppliers more like customers certainly does not preclude the buying organization from saying "no" to a supplier request or even switching suppliers if it becomes apparent over time that the supplier-partner is no longer an asset to the supply chain. What it does is provide the buying organization with much needed information about how their suppliers view them as a customer, which can help overcome the perception gap in the relationship, which would seem to help significantly in the establishment of trust that so many organizations report as critical for successful buyer-supplier relationships. Likewise, it provides a means to uncover opportunities at the boundaries in the supply chain for true supply chain optimization to occur.

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