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LETTER FROM THE EDITOR

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Manuscripts

CLASSIFYING THE STABILITY SCORES OF THE BIG-THREE AMERICAN AUTOMOTIVE COMPANIES USING DEA WINDOW ANALYSIS

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ABSTRACT

This paper evaluates the stability of the efficiency scores of the three largest American automotive companies over three 4-year windows (1986-1989, 1990-1993, and 1994-1997). The study employs a nonparametric technique called Data Envelopment Analysis (DEA), in particular DEA window analysis, to evaluate the stability of the companies' efficiency. The automotive firms are classified based on their stability scores, using cluster analysis into four groups: efficient stable, efficient unstable, inefficient unstable, and inefficient stable. The results of two DEA models (CCR and BCC) are consistent to a great extent in classifying the firms over the three 4-year windows. Both models indicate that, for the studied period, Ford Motor Company is classified by both DEA models 92% (22/24) of the time as either efficient stable or efficient unstable. Chrysler Corporation is classified 71% (17/24) of the time as efficient stable or efficient unstable. On the other hand, General Motors Company is classified 67% (16/24) as efficient stable or efficient unstable. The empirical results reveal that each company could have reduced advertising spending, total assets and number of employees while maintaining sales volume and market share during the period.

BACKGROUND

The efficiency in the auto manufacturing industry has been, over the last decade, analyzed in two major studies (Womack, Jones, and Roos, 1990; Fuss and Waverman, 1993). However, there are not many articles that have addressed the efficiency performance of the U.S. big-three auto companies using Data Envelopment Analysis (DEA). To fill this void, this paper is intended to evaluate and analyze the stability of the efficiency of U.S. automotive companies during the period 1986-1997. DEA is used to measure efficiency when there are multiple inputs and outputs and there are not generally accepted weight for aggregating inputs and aggregating outputs. The present study has a significant marketing orientation in the sense that most of the considered inputs and outputs are basically measures of marketing phenomena. In the marketing literature, a number of scholars applied DEA in order to gauge and analyze efficiency. Notable examples include the study of Charnes *et al*. (1985), who have first discussed potential applications of DEA in retailing and sales research. Metzger (1993) presented DEA methods in measuring the effects of appraisal and prevention costs on productivity. Chebat *et al*. (1994) used DEA to assess the degree to which allocation of marketing resources affects the corporate profits of Canadian firms. Boles, Donthu, and Ritu (1995) proposed DEA to evaluate salesperson performance. Horsky and Nelson (1996) evaluated and benchmarked the salesforce size and productivity by using DEA. Donthu and Yoo (1998) utilized DEA to assess the productivity of 200 retail stores. Thomas *et al*. (1998) evaluated the efficiency of 552 individual stores for a multi-store, multi-market retailer using DEA. Pilling, Donthu, and Henson (1999) employed DEA to adjust sales performance by territory characteristic, derived from the Census of Retail Trade. The above review reveals the absence of advertising applications from the literature. Although a number of authors (e.g., Asker and Carman 1982; Tull *et al*. 1986) have examined the issue of advertising efficiency within the context of a single firm, there has not been work involving studying the relative efficiency of advertising spending of competing firms in the same industry. DEA can be instrumental in achieving such a goal.DEA is intended to measure the relative efficiencies among DMUs (Decision Making Units) and enables direct measurements of efficiency. DEA formulates a series of linear programming models, one for each DMU. These models can identify the relatively efficient DMUs and accord them a rating of value one, or 100% efficiency. The major advantages of DEA over traditional ratio and regression approaches include (1) DEA doesn't require a knowledge of a production function linking input variables with output variables; (2) In DEA, there is no need to assign rigid weights to inputs or outputs; and (3) DEA offers management a variety of useful insights including relative productivity scales and efficiency gaps within different inputs and outputs that help in indicating causes for inefficiency (Charnes *et al.* 1994). The most important consideration in any DEA application is the selection of model specification including input and output variables. Regression analysis can empirically infer at least potential input/output relationships, while DEA only presumes that such relationships exist. Researchers, therefore, must make sure that 1) outputs are statistically related to inputs, 2) the variables represent management overall goals and policies, and 3) the appropriate model is used. Also considerable effort should be spent in selecting the number of comparable DMUs to include in the analysis. The number of DMUs to consider in the analysis is a controversial issue. While Ali *et al.* (1988) and Banker and Maindiratta (1986) recommend that in traditional DEA the number of units should be at least twice the sum of the inputs and outputs, Golany and Roll (1989) warn that the larger the number of units in the analysis set, the lower the homogeneity within the set and thus increasing the possibility that the results may be affected by some exogenous factors which are not of interest. For example, small assembling automobile firms would not be meaningful when compared with the big-three companies in the United States. In the automotive and airplane manufacturing industries, a few large companies dominate the market. In this situation, DEA window analysis becomes more appropriate. DEA *window* analysis is used to track the efficiency over time. It pools the observations of several consecutive years (e.g., 4 years) as an 4-year *window.* It then reveals the efficient DMUs in this 4-year period by using DEA models. Thus the efficient DMU denotes the best performance in the 4-year period (Thore *et al.,* 1996). One of the limitations of DEA is that it measures the technical efficiency (optimizing the use of resources), leaving out the allocation efficiency (allocating the available resources). Moreover, DEA is very sensitive to outliers, which make the selection of DMUs critical. Outliers may greatly affect the shape of the efficient frontier and alter the efficiency estimates (Donthu and Yoo, 1998). In addition, self-identifier and near-self-identifier problems may also arise (Bauer *et al*. 1998). That is, some DMU may be self-identified as 100% efficient not because they dominate any other DMUs, but because no other DMUs or linear combination of DMUs are comparable in the model. However, in recent years, many researchers have focused on DEA sensitivity analysis aspects (Charnes, Rousseau, and Semple, 1996; Seiford and Zhu, 1998; Zhu, 2001). The use of sensitivity and stability analyses of efficiency scores of DEA models should make decision makers more confident in the DEA results.

RESEARCH FRAMEWORK

The research framework for this study is depicted in Figure 1. The research framework consists of the following steps:

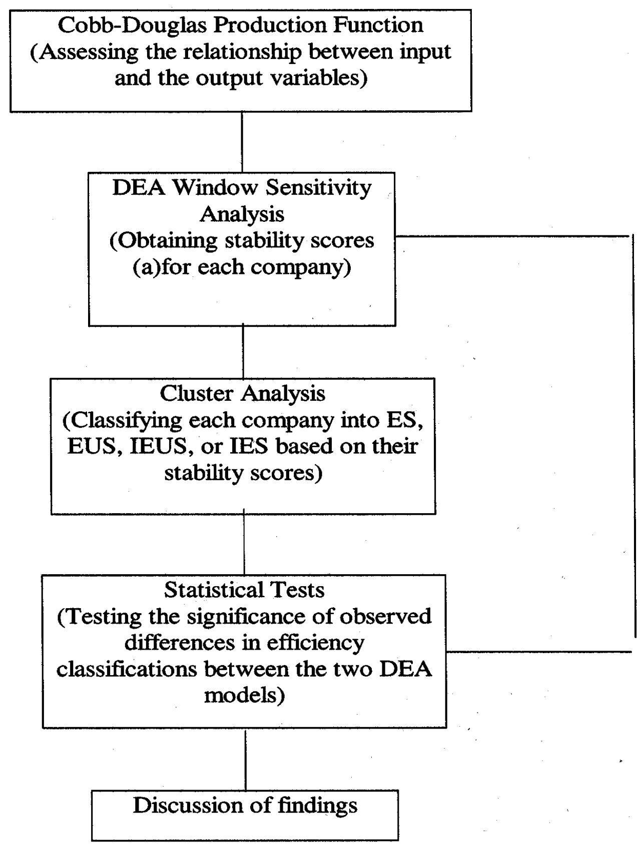
a) The Cobb-Douglas Production Function is used to assess the relationship between input and output variables.
b) DEA window sensitivity analysis is performed to obtain the stability scores for each company.
c) Cluster analysis is used to classify the automotive firms based on their stability scores into Efficient Stable (ES), Efficient Unstable (EUS), Inefficient Unstable (IUS), and Inefficient Stable (IES) classes.
d) Statistical tests are used to test for significant correlations between the results of the two DEA models (CCR vs. BCC), and the significance of any observed disagreements in efficiency classifications.

A. The Cobb-Douglas Production Function

The rationale of our approach relies upon the macroeconomic production model. The Cobb-Douglas production function has been extensively applied to evaluate firm performance from the productivity point of view (Allison and English, 1993). The Cobb- Douglas function may be formulated as follows.

Y = K CA LB
where
Y = the output,
C = the capital inputs,
L = the labor inputs,
A = the elasticity coefficient of capital inputs,
B = the elasticity coefficient of labor inputs, and
K = scaling constant.

Figure 1. Research Framework



Comparable to the Cobb-Douglas function, this paper uses the following indicators for inputs: total assets (in billions of USD), number of employees (in thousands), and advertising expenditures (in millions of USD). The outputs consist of net sales (Y_1) (in billions of USD), and market share (Y_2) (in percentage of the U.S. market). Thus the Cobb-Douglas function is modified to take on the following form:

$$Yi = eK * ADVETA * TOTASB * EMPLOYC \quad , \quad i = 1, 2. \qquad (1)$$

Observe that equation (1) is a non-linear model. It needs to be linearized before using the Ordinary Least Squares (OLS) procedure for its estimation. Taking the natural logarithm of both sides of (1) produces:

$$LnY_i = K + A .Ln (ADVET) + B .Ln (TOTAS) + C .Ln (EMPLOY), i= 1,2. \quad (2)$$

where

ADVET = observation of input of advertising spending,
TOTAS = observation of input of total assets,
EMPLOY = observation of input of employees,
A = elasticity coefficient of advertising,
B = elasticity coefficient of total assets,
C = elasticity coefficient of employees, and
K = scaling constant.

Equation (2) presents a model of decreasing returns to scale for increased total assets, advertising spending, and number of employees. The model allows for interaction effects and the coefficients can be interpreted as elasticities. Equation (2) also assumes for simplicity that each input (expressed in terms of its natural logarithm), considered separately, has the same effectiveness on a given output (expressed in terms of its natural logarithm) across the three manufacturers.

B. DEA Window Analysis

Since we have only three DMUs (three companies) each year, three 4-year windows analysis were conducted to get the efficiency scores for DMUs during each 4-year window (3*4 = 12 DMUs). The rationale for dividing into four-year periods is that a product cycle in the automotive industry lasts about four years. Each generation for a specific car brand, with a few exceptions, is held approximately four years before being supplanted by the next generation, given the fierce competition and quickly updating technology in the industry (Fuss and Waverman, 1993). It is recommended to start the analysis by using the original DEA model (CCR) introduced by Charnes, Cooper, and Rohdes (1978) because it reveals the differences among the DMUs in the most unforgiving manner (e.g., it has the largest reference set). The results of the BCC model, which was introduced by Banker, Charnes, and Cooper (1984), are also compared with the results of the CCR model in this study. Therefore, two DEA models (CCR and BCC) input oriented formulations are used to evaluate the stability classification of the efficiency of the three companies.

C. DEA Sensitivity Analysis

For each company, the sensitivity measure or stability percentage (α) is calculated by solving certain linear programming problems developed by Charnes, Rousseau, and Semple (1996). This particular linear programming formulation calculates α, the percentage radius of change in the input-output space within which a DMU's classification remains unchanged. It should be noted that a positive value of α means that the DMU is an efficient one, while a negative value means that the unit is inefficient. On the other hand, the absolute value of α is the percentage within which the DMU's Classification remains unchanged.

D. Cluster Analysis

For each separate group (efficient and inefficient), univariate cluster analysis is performed on the absolute values of the stability scores (α) to create stable and unstable categories. The stable group has high absolute value of α and the unstable group has low absolute value of α. Thus, resulting in four final classifications; Efficient Stable (ES); Efficient Unstable (EUS); Inefficient Unstable (IEUS) and Inefficient Stable (IES).

E. Statistical Tests

Since each automotive firm is categorized as efficient stable, efficient unstable, inefficient unstable, or inefficient stable under each DEA model (CCR and BCC), several nonparametric procedures could be used to test the significance of any observed disagreement in efficiency classifications. One test is the Friedman test for dependent samples with classes ranked as: ES=4, EUS=3, IEUS=2, and IES=1. In addition to that test, Spearman Correlation coefficient could be used to test for significant correlations between the stability scores related to the two DEA models.

DATA COLLECTION

Standard and Poor's Compustat database was the source for the financial data related to companies net sales, total assets, and number of employees. *Advertising Age* was the source for the advertising expenditures from 1986 to 1997. The market share data was obtained from *Ward's Auto World* databank.

EMPIRICAL RESULTS

This section reports the results of estimating the Cobb-Douglas production function in assessing the relationship between the input and the output variables. It also reports the results of the analysis of the stability scores for the automotive companies over the three 4-year windows.

The Cobb-Douglas Production Function Estimation Results

Although it is always better to estimate the sales volume and market share equations jointly using the method of seemingly unrelated regression, SUR, (Zellner, 1962) there are circumstances when it is just as good to estimate each equation separately. One of such circumstances is actually in conformity with our situation. Indeed, some advanced algebra is needed to prove that OLS and SUR give *identical* estimates when the same explanatory variables appear in each equation (Hill, Griffiths, and Judge, 1997). Therefore, the two equations related to sales volume and market share for the U.S. automotive industry would be estimated separately using OLS.

After adding error terms and applying White's procedure for heteroskedasticity correction, Table 1 displays the regression results of equations (2). The results show that the sales volume is statistically related to the input variables (total assets, advertising expense and number of employees). The regression model (dependent variable = sales volume) has an F- statistic of 274.50, with p-value less than 0.001, and an adjusted R-square of about 0.96. All the input explanatory variables' standardized coefficients (e.g. advertising, employees, and total assets) are significantly different from zero with t-statistic of p-value less than 0.01. Also the F- statistic for the regression model (dependent variable = market share) is 79.65, with p-value less than 0.001, and adjusted R-square of about 0.89. Again, the market share output is statistically related to advertising (p-value less than 0.05), total assets (p-value less than 0.10), and employees (p-value less than 0.01).

Table 1
OLS RESULTS OF THE RELATIONSHIP BETWEEN EACH DEPENDENT VARIABLE AND ALL INDEPENDENT VARIABLES

	Dependent Variable Y1 = Sales Volume				Dependent Variable Y2 = Market Share			
Independent Variables	Parameter Estimate	Probability >|T|	White's Probability >|T|	VIF	Parameter Estimate	Probability >|T|	White's Probability >|T|	VIF
Advertising	0.5231	0.0000	0.0000	1.32	0.3605	0.0175	0.0135	1.32
Total assets	0.1943	0.0000	0.0000	1.06	0.1107	0.1421	0.0932	1.06
Employees	0.6324	0.0000	0.0000	1.37	0.5214	0.0000	0.0000	1.37
F-Statistics	274.50***				79.65***			
Adj. R-Square	0.96				0.89			
Durbin - Watson	1.997				1.851			

Note: all variables are expressed in terms of their natural logarithms.
*** p < .01

The small values of variance inflation factors (VIF's) shown in Table 1, suggest that multicllinearity is not an issue in any of the models (Neter, Wasserman, and Kutner, 1990). Furthermore, there is no evidence of the presence of serial correlation in any of the models (Durbin and Watson, 1951) adding more credence to the robustness of the model. The inputs and outputs variables used are statistically related, thus satisfying the variable requirements of DEA applications (Golany and Roll, 1989). The DEA results are reported next.

Comparing Companies over Three Four- Year Windows

The performance of each manufacturer is examined for three 4-year window periods. The performance of each company during 1994-1997,1990-1993, and 1986-1989 are compared. In conducting such analysis related to each window, a certain company in a particular year is considered as a separate DMU by itself. The linear programming problems (see Charnes, Rousseau, and Semple, 1996) are applied for the entire 4-year window, one at a time for each DMU, resulting in obtaining the stability scores for a total of 12 DMUs. The stability analyses of these three four-year windows are summarized in Table 2. Most of the Chrysler and Ford's years are efficient unstable (for both BCC and CCR models). On the other hand, most General Motors' years (6/12) are inefficient-unstable from the CCR model results, and (9/12) are efficient unstable from the BCC model results. It is worth mentioning that other 4-year windows results (1993-1996, 1992-1995, 1991-1994, etc.) arrive at similar conclusions to those related to the above three 4-year windows.

Table 2
STABILITY SCORES FOR THE SELECTED THREE 4-YEAR WINDOWS*

Window 94-97			Window 90-93			Window 86-89		
DMU	CCR stability	BCC stability	DMU	CCR stability	BCC stability	DMU	CCR stability	BCC stability
CR97	-0.0301	-0.0243	CR93	**0.08251**	**0.09526**	CR89	0.08691	0.10147
CR96	**0.04769**	0.06399	CR92	0.0306	**0.06579**	CR88	0.00068	0.06849
CR95	-0.0355	-0.0284	CR91	0.02259	**0.05517**	CR87	-0.0166	-0.0018
CR94	**0.08326**	**0.25446**	CR90	-0.004	0.01457	CR86	**0.32966**	**0.28617**
FD97	-0.0163	0.02323	FD93	0.0365	**0.06612**	FD89	0.00755	0.02418
FD96	0.03153	0.04775	FD92	0.02253	0.02284	FD88	0.01707	0.02836
FD95	0.01804	0.01863	FD91	0.00553	0.00684	FD87	-0.0279	0.00455
FD94	0.00366	0.00996	FD90	**0.09778**	**0.09894**	FD86	0.07669	0.09738
GM97	-0.0228	0.07955	GM93	0.0034	0.04601	GM89	-0.1352	0.02362
GM96	-0.0162	-0.0023	GM92	0.02269	0.04903	GM88	0.0896	0.09513
GM95	0.0075	0.0084	GM91	-0.0205	-0.0783	GM87	-0.0466	**0.19312**
GM94	0.02225	0.02757	GM90	-0.0155	0.01795	GM86	0.02739	0.08467

*. Numbers in bold mean efficient stable

Table 3, derived from Table 2, shows the number of efficient years during each 4-year window for both DEA models. GM received the least number of efficient years (16/24). This suggests that GM is the least efficient manufacturer compared to the other two competitors. On the other extreme, Ford enjoyed the largest number of efficient years during the three 4-year windows (22/24). Chrysler received (17/24) as efficient. It should be noted that none of the three companies is classified as inefficient stable in the three 4-year windows analysis

Table 3
THE NUMBER OF EFFICIENT YEARS DURING EACH 4-YEAR WINDOW FOR CCR AND (BCC) MODELS

Company	# of efficient years 1994-1997	# of efficient years 1990-1993	# of efficient years 1986-1989	Total
Chrysler	2 (2)	3 (4)	3 (3)	8 (9)
Ford Motors	3 (4)	4 (4)	3 (4)	10 (12)
General Motor	2 (3)	2 (3)	2 (4)	6 (10)

The correlations between the stability scores of the two models (CCR and BCC) for each one of the three 4-years windows are significant as shown in Table 4. One can say that the results of the two DEA models are in agreement to a great extent with respect to the automotive firms' stability scores. It should be noted that when the stability scores for the three 4-year windows are pooled together, the correlation between the two models was also significant (Spearman's correlation coefficient r = 0.679; p-value = 0.000005).

Table 4
SPEARMAN'S CORRELATION COEFFICIENT OF STABILITY SCORES OF CCR VS. BCC

4-year windows	Spearman Correlation Coefficient r (p-value)
1994-1997	0.671 (0.016)
1990-1993	0.930 (0.00001)
1986-1989	0.601 (0.0386)

The Friedman test (for ordered classes) is employed using the data depicted in Table 2 to test the hypothesis of no difference in efficiency classifications (ES, EUS, IEUS, and IES) between the two DEA models. The results of the Friedman test for two of the three 4-year windows are significant (p-value = 0.0254; p-value = 0.0832 for window 90-93 and window 86-89, respectively), indicating that the observed efficiency classifications are significantly different between the two DEA models for these two windows. The result of the Friedman test for the third 4-year window (94 - 97 window) is not significant, indicating that the observed efficiency classifications are not significantly different between the two DEA models for that window. These findings imply that DMUs classification results obtained from the two DEA models become more consistent with one another upon using the stability score as an additional dimension for classification. It is known from the literature that when the efficiency score is used as the sole classification dimension, the CCR model generates fewer efficient DMUs than the BBC model does.

IMPILICATIONS AND CONCLUSIONS

This study employs two DEA models in conjunction with cluster analysis in order to classifying stability scores of the U.S. big-three auto companies. The results of both models (CCR and BCC) indicate that Ford was the most efficient leader during each consecutive four-year period, or product cycle. General Motors was the most inefficient company in the industry. Chrysler is positioned to lie between these two extremes. These findings are consistent with the point of view of industry experts (e.g., Vasilash, 1996 and Valsic, Naughton, and Kerwin, 1998).

Implications for Management

The authors are fully aware that the results of this study will be welcomed by the manufacturer placed first (Ford) and disregarded by the one placed last (General Motors). The worst performer will question these efficiency estimates by arguing that important inputs and/or outputs have not been incorporated in the analysis, or that the DEA CCR and BCC models utilized in deriving the conclusions come into question. The best performer, on the other hand, will be sufficiently satisfied without bothering about these shortcomings. However, DEA results are descriptive (diagnostic) in nature rather than perspective. Thus, management should examine in depth the results of DEA models in order to make appropriate corrective decisions. For example, efficiency scores and slack variables obtained through solving the original DEA models, reveal that each company could have reduced advertising spending, total assets and number of employees while maintaining sales volume and market share during the studied period. A viable way to reduce waste in advertising spending is to adequately test ad campaigns that are already running. Strategies for dealing with excess capacity includes better production planning and control processes, reviewing the level of product variety in the face of conflicting cost and revenue implications, and selling money-losing businesses. A common strategy to deal with a surplus of employees is laying some of them off. By working closely with the United Auto workers to avoid potential strikes, the side-effects of such action can be minimized.

The additional classification of DMUs into stable or unstable status would allow management to have more confidence in their conclusions about the performance of the DMUs. As a result, management should seek and retain efficient stable DMUs and avoid or change the situation of inefficient stable ones. Management should also carefully monitor efficient unstable DMUs and take appropriate measures to keep them efficient. On the othert hand, management may adopt radical changes with respect to inefficient unstable DMUs. For example, in the summer of 1998, General Motors swapped brand-based operating divisions for a centralized marketing organization supported by a new field sales and marketing system to boost efficiency.

Implications for Researchers

Since there are not many studies that have evaluated the efficiency performance of the U.S. big-three auto companies using DEA technique, this study has intensively employed DEA sensitivity analysis in classifying the stability scores of the big-three auto companies in the U.S. Its major contribution is that it provides a post analysis for DEA results. Many researchers have employed DEA models in many applications; however, they have used only efficiency scores to draw their conclusions. This study does not only use efficiency scores in drawing its conclusions, but also calculates stability scores, which provide investigators with information on how efficiency scores are robust to any changes in the values of inputs or outputs. In addition, this study employs cluster analysis to classify DMUs into four distinct groups: Efficient Stable (ES), Efficient Unstable (EUS), Inefficient Unstable (IEUS), and Inefficient Stable (IES) in order to provide management with reliable conclusions. One direction for future research is to compare U.S. auto companies to its counterparts in other countries such as Japan and Europe. Another direction would be to examine the efficiency of brands within the three companies. A third plausible direction for future research would be to compare DEA results with other traditional methods of evaluating efficiency such as ratio analysis and production functions.

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MINIMUM COST MODELING FOR HIERARCHICAL STORAGE REALLOCATION USING DYNAMIC USAGE FREQUENCIES

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ABSTRACT

In computer information systems, some programs are used more frequently than others producing skewed distributions of program usages. We investigate the claim that static views of program usage frequencies are insufficient when they are used for storage allocation decisions making it necessary to study the implications of the use of dynamic frequencies in storage allocation.

The use of dynamic frequencies provides a natural extension to previously presented static cost model literature for hierarchical storage allocation. In our work, we present the value of incorporating dynamic usage frequencies into program usage cost models. Thus, an optimization-based cost modeling methodology using Simon's Model for dynamic hierarchical storage allocation is presented.

To illustrate, a simple example of program storage allocation is presented in both static and dynamic form. Cost-saving comparisons are then discussed.

INTRODUCTION

One problem faced by organizations in today's rapidly changing field of computer information systems is the consumption of storage capacity due to the growing base of software assets. Research has shown that very few firms effectively monitor program usage (Willet, 1994). Storage management issues arise when many of the programs occupying valuable storage space are used infrequently. Many IS managers simply buy more primary storage when they feel it is necessary instead of performing maintenance.

Many application programs in a firm are subject to decreases as well as increases in usage rates. The problem is that the usage rate of an individual software item is dynamic. There is no feasible way to predict the behavior of each individual program in an organization. Instead, it is more practical to provide a methodology for focusing on those programs whose changing usage is critical to storage allocation and cost minimization.

With a better understanding of normal program usage behavior, organizations can develop policies based on easily understood criteria. Simon's Model has been well studied in literature concerning information usage (Simon, 1991). Program usage can also be studied using the model, making it the tool of choice to develop such criteria. In turn, we will show that it is possible to create organizational policy based on program usage observations.

The true value in deriving a policy using Simon's Model is the relative ease that an organization can assess its own model parameters. Once model parameters are evaluated, a firm would be able to determine the category into which their software falls. Each category would provide a recommendation for the intervals at which the "significant few" should be assessed for usage. The cost of storage allocation could then be minimized.

SUPPORTING LITERATURE

While investigating various algorithms developed for the purpose of optimizing storage in multi-level storage systems, it was found that the models developed by P. Chen (1973) and Ramamoorthy & Chandy (1970) assumed a static, or constant, usage frequency. Both models are optimization models that serve to either minimize storage cost or minimize average access time. The focus of Chen's model was on the placement of files using various types of storage devices that minimize cost. In the work of Ramamoorthy & Chandy, their model involved the placement of programs and associated data in a storage hierarchy to minimize access time.

General observations from the study of Simon's Model indicate that it is possible to isolate dynamic usage scenarios prevalent in organizational program usage behavior (Simon, 1968). Simon's model provides us with a powerful mechanism for studying program usage scenarios. Therefore, we adapt the model in a dynamic way by expressing a (alpha - an increasing usage rate) and ? (gamma - a decreasing usage rate) as functional values. This adaptation provides us new insight into the interrelation of program entry and program aging (Simon, 1991).

By incorporating Simon's Model, we have the ability to categorize usage patterns. For example, we can determine which software programs fall into the category of the "trivial many." Research thus far indicates that in many firms at least 80% of programs fall into this category (Willet, 1994). Thus, in most organizations, a very large portion of programs can be eliminated from the group requiring maintenance attention. Additionally in many organizations, there is usually a very small portion of programs whose usage consistently remains in a high usage ranking position. It would also be reasonable to eliminate these programs from the group requiring maintenance since they show little to no decay in usage.

Once the group of programs of concern in the "significant few" is identified, it then becomes valuable to examine the changes in their usage. In order for organizations to have the ability to establish a policy for better management of their storage assets, we extend the research of P. Chen and Ramamoorthy & Chandy. We develop and present the methodology: Dynamic Storage

Reallocation with Cost Minimization, a cost-oriented optimization model for the assignment of programs to various levels of storage.

THE OPTIMAL STORAGE ALLOCATION HIERARCHY MODEL

The model developed here is targeted toward the placement of programs in different storage media, but it is also applicable to the placement of data. We have chosen to concentrate on program storage in order to accommodate programs consisting of a variable number of memory blocks that are assigned to a single storage medium. If data files are considered in the storage hierarchy, then one can assume that the data can be divided into equal size blocks, and blocks of the same file may be stored on different devices in the memory hierarchy.

Model Assumptions

1. Let M denote the total number of devices in the storage hierarchy.

2. For each device j, the cost per block is Cj for devices j = 1, 2, . . . , M. It is assumed that Cj is a known, constant value. Also, it is proportional to the efficiency with which the program can be retrieved from storage. That is, a program stored in primary storage will have a higher associated cost per block than a program that is stored in some other secondary storage device. Cost figures for the use of primary and secondary storage devices are generally expressed in dollars per megabyte. Ghandeharizadeh, Ierardi and Zimmerman (1994) make reference to costs associated with such storage options.

3. Let L denote the total number of programs, where each is stored in a file consisting of Ni blocks for i = 1, 2, . . . , L. Assume that the blocks of a program cannot be separated from the program file on different media. Namely, blocks of a program file cannot be divided between several storage devices.

4. Suppose that decision variable Xij = 1 if program i is assigned to device j, or 0 if program i is not assigned to device j. Thus:

$$\sum_{j=1}^{M} X_{ij} = 1.$$

5. Let fi be the reference frequency for program i in per unit time. Here, the time unit is expressed in terms of cycles, where a cycle is defined as the number of total usages over an observed distribution of frequencies. Thus, the total request rate (?j) for device j is found below. We assume here that a single program is allocated to only one storage device, and any usage frequency profile (fi) will reflect only the usage history since the previous allocation.

$$\lambda_j = \sum_{i=1}^{L} f_i X_{ij}.$$

6. It is assumed that one program is transferred per input/output request. The service time for each device is presumed to be a random variable that varies accordingly for input/output requests due to the electromechanical nature of storage devices. Thus, request service time is assumed to be exponentially distributed with a mean of $1/\mu j$ for $\mu 1$,? $\mu 2$,? . . . , $\mu M > 0$, where μj is the service rate of device j. In order to prevent the queue length for requests from growing without bound, it is required that ?j < μj. Namely, the overall request rate to a device must be less than the service rate.

7. It is also necessary to define BSj as the maximum allowable number of blocks that can be stored on device j. This is a constant value that is assigned as blocks of storage are added.

Minimum Cost Storage Allocation Model Formulation

From the assumptions stated above, a cost minimization model for the allocation of programs to various levels of storage can be stated as follows:

Minimize Cost

$$\sum_{j=1}^{M} C_j \sum_{i=1}^{L} N_i X_{ij} \tag{1}$$

Subject To

$$\sum_{j=1}^{M} X_{ij} = 1 \qquad \text{for } i = 1, \ldots, L \tag{2}$$

$$\sum_{i=1}^{L} N_i X_{ij} \leq BS_j \qquad \text{for } j = 1, \ldots, M \tag{3}$$

$$\sum_{i=1}^{L} f_i X_{ij} \leq \mu_j \qquad \text{for } j = 1, \ldots, M \tag{4}$$

A PROGRAM STORAGE ALLOCATION EXAMPLE

Suppose we have two storage devices. In addition, assume we have five program files, and we want to allocate them between the two devices. Further, assume that the cost of the two storage devices are C1 = \$4/block and C2 = \$2/block. Also for the example, assume that the usage frequencies of the programs are known. (Note: The assumption of known, or static, frequency is a limitation to storage allocation cost modeling.) Finally, suppose for this example that the service rates for each storage device are $\mu 1 = 30$ and $\mu 2 = 20$. Table 1 below summarizes the example computer information system where i is the index of programs, Ni is the block size of each program, and fi denotes the usage frequency of program i.

Table 1 Block Sizes and Usage Frequencies for the Static Storage Allocation Example		
i	N_i	f_i
1	40	17
2	20	9
3	30	5
4	40	5
5	75	13

Thus, the example can be modeled as a storage allocation linear programming problem with L = 5 and M = 2.

Capacity constraints for the two storage devices are defined by total block sizes BS1 and BS2. For the example, we let BS1 = 200 and BS2 = 500. Appendix 1 contains the example problem's storage allocation cost formulation. To solve this optimization problem LINDO/PC, Release 6.1, was employed. Initial results are presented in Table 2 below.

Table 2 Storage Resource Allocation Results Optimal Objective Function Value (Cost) = $640	
Variable	Value
X_{11}	1
X_{12}	0
X_{21}	0
X_{22}	1
X_{31}	0
X_{32}	1
X_{41}	0
X_{42}	1
X_{51}	1
X_{52}	0

The initial results indicate that programs 1 and 5 were allocated to device 1, and programs 2, 3 and 4 were allocated to device 2. Implementation of this algorithm would cause the programs to be moved to their appropriate locations in order to optimize storage cost. Intuitively, one might think that files will always be allocated to the cheaper storage device in order to minimize cost. In this model, program access is constrained by the service time requirements that would ensure that some files are stored on the faster and more expensive storage medium.

At this point we have solved the storage allocation problem using a single usage frequency profile. The contention of this paper is that program usage frequencies are not static over time. There are many occurrences such as changes in technology, changing organizational needs, and new program production that cause program usage behavior to be dynamic. We know that this dynamic behavior can be captured using Simon's Model to incorporate the dynamic parameter values alpha and gamma.

These parameters are described by Simon and Van Wormer (1963) as the entrance rate of new items and the decay, or aging rate, of old items, respectively. Many studies have been performed that demonstrate the interaction between alpha and gamma. It is reasonable, in the context of this study to assume that alpha is increasing, while gamma is decreasing. In our use of alpha and gamma, both parameters are functions of the total number of usages and maximum number of programs.

INCORPORATING SIMON'S MODEL FOR DYNAMIC STORAGE REALLOCATION

With insight gained through the study of dynamic usage frequencies of Simon's Model, we extend the static cost optimization storage allocation model presented earlier. We call this modeling methodology: Dynamic Storage Reallocation with Cost Minimization. The process for implementation is shown in Figure 1. Also, for the current example, we show the effect of using dynamic usage frequencies on the model.

In the static example, we started out with 5 programs totaling 49 usages (sum of all usage frequencies). Thus, we estimate alpha to be 0.102 (total number of programs/sum of all frequencies). We also assume that alpha is increasing and gamma is decreasing. That is, we are observing the changing usage distribution under the assumption that new programs are "arriving" at a rate of alpha, which in turn causes a "decay" at a rate gamma in the usage of the existing programs. Using Simon's Autoregressive Model with increasing alpha and decreasing gamma, we observe the frequency distribution when alpha is estimated to be 0.20 (Chen, Chong and Tong, 1993). Table 3 below presents frequency data for the initial allocation of programs made according to the original optimal solution. Appendix 2 contains the example problem's storage allocation cost formulation.

Note that in the dynamic example, the increasing value of alpha has caused the addition of 3 new programs. We then observe the changes in allocation to the appropriate storage medium that occur when the model is adjusted for the entry of these new programs in order to minimize cost.

Figure 8 **Figure 1**
Dynamic Storage Reallocation Methodology

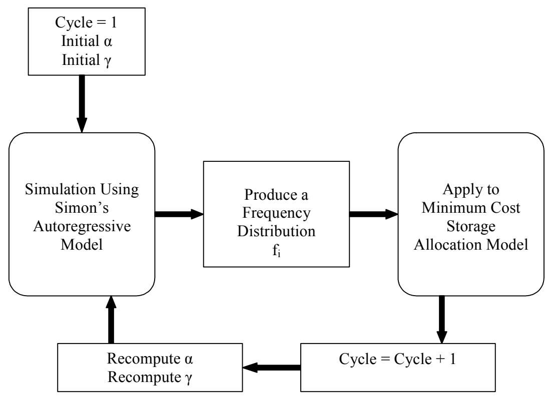

Table 3 Block Sizes and Usage Frequencies for the Dynamic Storage Allocation Example (a = 0.20)		
i	N_i	f_i
1	40	10
2	20	6
3	30	4
4	40	3
5	75	5
6	30	4
7	30	6
8	30	2

Results of the model indicate an increased objective function value (cost) of $770. This implies that the addition of the 3 new programs increased the cost by $130 (770 - 640). It is interesting to compare these results to those that would have been incurred if the model did not account for all dynamic changes. If that were the case, the three new programs would have simply been stored on device 1, the more expensive storage medium. We make this assumption since most organizations choose to store new programs on the fastest medium. With the addition of these new programs, and no change made to the allocation of existing programs, the total cost incurred would have been $1000. This cost was computed by adding the cost of the initial allocation to the cost of allocating 3 new programs to device 1 [(3*30*4)+640]. Thus, for the static example, the savings were $1000 - $770 = $230.

EXAMPLE CONSIDERING FURTHER REALLOCATION

We now consider a second dynamic example that considers a different value for alpha. In this example we set alpha at 0.40. Our goal here is to show that there will still be a cost improvement as alpha increases and gamma decreases. Again using Simon's Model, a frequency distribution was generated according to these new parameters. Table 4 below summarizes the second system. Appendix 3 contains the example problem's storage allocation cost formulation.

Table 4
Block Sizes and Usage Frequencies for the Second Dynamic Storage Allocation Example
(a = 0.40)

i	N_i	f_i
1	40	9
2	20	5
3	30	4
4	40	3
5	75	3
6	30	3
7	30	5
8	30	1
9	20	2
10	20	3
11	20	2
12	20	2
13	20	1
14	20	1
15	20	1
16	20	1
17	20	1
18	20	1
19	20	1
20	20	1

As in the first example problem, the results were computed as if no reallocation had been done since the last run. Without dynamic allocation, the total cost would be estimated at $1730 [(12*20*4)+770]. Optimally solving the second dynamic example problem, we obtain a storage cost of $1450 producing a cost saving of $280.

We note that our results now indicate that the capacity constraints for the service rates have zero slack. Thus, we have reached the maximum number of program usages that can be handled by the simple system.

COST IMPLICATIONS FOR VARYING ALPHA AND GAMMA

The examples presented in the above sections demonstrate that cost savings can be realized with the consideration of dynamic usage frequencies for storage allocation, and present the impact of savings from the effect of sensitive changes to alpha and gamma. In order to perform cost savings sensitivity analyses, simulation programming with increasing alpha rates and decreasing gamma rates was designed and implemented. The combination of an increasing alpha and decreasing gamma represents an intuitive scenario of program usage behavior. Table 5 below summarizes the results. The simulation program was executed at six different intervals with varying degrees of alpha and gamma. For each of these executions, two storage devices were again assumed (M = 2).

Table 5
Summary of Cost Saving Results from Simulation Execution with varying degrees of a and ?

α	γ	Number of Programs	Optimal Cost (Dynamic)	Optimal Cost (Static)	Total Cost Saving	Cost Saving per Program
0.10	0.95	3	$100	$200	$100	$33.33
0.41	0.90	6	$180	$300	$120	$20
0.59	0.76	12	$360	$540	$180	$15
0.72	0.62	20	$660	$1020	$360	$18
0.84	0.46	28	$1040	$1500	$460	$16.43
0.95	0.28	37	$1480	$2040	$640	$15.13

The results indicate that total cost savings continued to increase as the values of alpha increased, although the cost savings per program decreased slightly as the total number of programs increased. This is an intuitive result. Additionally, as the total number of programs increases, the limit for total block capacity is decreasing. Once the storage capacity for both devices reaches their limits, there would be no more savings until capacity is expanded.

CONCLUSIONS

We introduced the modeling methodology: Dynamic Storage Reallocation with Cost Minimization, and demonstrated the implications dynamic usage frequencies have on storage allocation. Viewing program storage allocation as a dynamic process will not only affect storage costs, but also affect the placement of programs under some service time constraint.

The methodology proposed in this research is a natural extension of the work by P. Chen and Ramamoorthy & Chandy, though it does have significant differences from those developed by the aforementioned authors. We have not taken into consideration mean response time constraints for individual storage requests, nor have we considered the possibility of allocating blocks of one file to different storage media. Both considerations present opportunities for future research.

The results of this research confirm that improvements in storage allocation costs can be made if files are allocated according to dynamic usage frequencies. In our simplistic example and simulation execution we studied a small sampling of programs for brevity in model formulation. Naturally, a problem of this type that models a complex, real storage allocation situation could grow to become quite large but can be handled by this approach.

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APPENDIX 1

Minimize Cost

$4*40*X_{11} + 2*40*X_{12} + 4*20*X_{21} + 2*20*X_{22} + 4*30*X_{31} + 2*30*X_{32} + 4*40*X_{41} + 2*40*X_{42} + 4*75*X_{51} + 2*75*X_{52}$

Subject To

$X_{11} + X_{12} = 1$
$X_{21} + X_{22} = 1$
$X_{31} + X_{32} = 1$
$X_{41} + X_{42} = 1$
$X_{51} + X_{52} = 1$
$40*X_{11} + 20*X_{21} + 30*X_{31} + 40*X_{41} + 75*X_{51} \le 200$
$40*X_{12} + 20*X_{22} + 30*X_{32} + 40*X_{42} + 75*X_{52} \le 500$
$17*X_{11} + 9*X_{21} + 5*X_{31} + 5*X_{41} + 13*X_{51} \le 30$
$17*X_{12} + 9*X_{22} + 5*X_{32} + 5*X_{42} + 13*X_{52} \le 20$

APPENDIX 2

Minimize Cost

$4*40*X_{11} + 2*40*X_{12} + 4*20*X_{21} + 2*20*X_{22} + 4*30*X_{31} + 2*30*X_{32} + 4*40*X_{41} + 2*40*X_{42} + 4*75*X_{51} + 2*75*X_{52} + 4*30*X_{61} + 2*30*X_{62} + 4*30*X_{71} + 2*30*X_{72} + 4*30*X_{81} + 2*30*X_{82}$

Subject To

$X_{11} + X_{12} = 1$
$X_{21} + X_{22} = 1$
$X_{31} + X_{32} = 1$
$X_{41} + X_{42} = 1$
$X_{51} + X_{52} = 1$
$X_{61} + X_{62} = 1$
$X_{71} + X_{72} = 1$
$X_{81} + X_{82} = 1$
$40*X_{11} + 20*X_{21} + 30*X_{31} + 40*X_{41} + 75*X_{51} + 30*X_{61} + 30*X_{71} + 30*X_{81} \le 200$
$40*X_{12} + 20*X_{22} + 30*X_{32} + 40*X_{42} + 75*X_{52} + 30*X_{62} + 30*X_{72} + 30*X_{82} \le 500$
$10*X_{11} + 6*X_{21} + 4*X_{31} + 3*X_{41} + 5*X_{51} + 4*X_{61} + 6*X_{71} + 2*X_{81} \le 30$
$10*X_{12} + 6*X_{22} + 4*X_{32} + 3*X_{42} + 5*X_{52} + 4*X_{62} + 6*X_{72} + 2*X_{82} \le 20$

APPENDIX 3

Minimize Cost

$4*40*X_{11} + 2*40*X_{12} + 4*20*X_{21} + 2*20*X_{22} + 4*30*X_{31} + 2*30*X_{32} + 4*40*X_{41} + 2*40*X_{42} + 4*75*X_{51} + 2*75*X_{52} + 4*30*X_{61} + 2*30*X_{62} + 4*30*X_{71} + 2*30*X_{72} + 4*30*X_{81} + 2*30*X_{82} + 4*20*X_{91} + 2*20*X_{92} + 4*20*X_{101} + 2*20*X_{102} + 4*20*X_{111} + 2*20*X_{112} + 4*20*X_{121} + 2*20*X_{122} + 4*20*X_{131} + 2*20*X_{132} + 4*20*X_{141} + 2*20*X_{142} + 4*20*X_{151} + 2*20*X_{152} + 4*20*X_{161} + 2*20*X_{162} + 4*20*X_{171} + 2*20*X_{172} + 4*20*X_{181} + 2*20*X_{182} + 4*20*X_{191} + 2*20*X_{192} + 4*20*X_{201} + 2*20*X_{202}$

Subject To

$X_{11} + X_{12} = 1$
$X_{21} + X_{22} = 1$
$X_{31} + X_{32} = 1$
$X_{41} + X_{42} = 1$
$X_{51} + X_{52} = 1$
$X_{61} + X_{62} = 1$
$X_{71} + X_{72} = 1$
$X_{81} + X_{82} = 1$
$X_{91} + X_{92} = 1$
$X_{101} + X_{102} = 1$
$X_{111} + X_{112} = 1$
$X_{121} + X_{122} = 1$
$X_{131} + X_{132} = 1$
$X_{141} + X_{142} = 1$
$X_{151} + X_{152} = 1$
$X_{161} + X_{162} = 1$
$X_{171} + X_{172} = 1$
$X_{181} + X_{182} = 1$
$X_{191} + X_{192} = 1$
$X_{201} + X_{202} = 1$

$40*X_{11} + 20*X_{21} + 30*X_{31} + 40*X_{41} + 75*X_{51} + 30*X_{61} + 30*X_{71} + 30*X_{81} + 20*X_{91} + 20*X_{101} + 20*X_{111} + 20*X_{121} + 20*X_{131} + 20*X_{141} + 20*X_{151} + 20*X_{161} + 20*X_{171} + 20*X_{181} + 20*X_{191} + 20*X_{201} \leq 200$

$40*X_{12} + 20*X_{22} + 30*X_{32} + 40*X_{42} + 75*X_{52} + 30*X_{62} + 30*X_{72} + 30*X_{82} + 20*X_{92} + 20*X_{102} + 20*X_{112} + 20*X_{122} + 20*X_{132} + 20*X_{142} + 20*X_{152} + 20*X_{162} + 20*X_{172} + 20*X_{182} + 20*X_{192} + 20*X_{202} \leq 500$

$9*X_{11} + 5*X_{21} + 4*X_{31} + 3*X_{41} + 3*X_{51} + 3*X_{61} + 5*X_{71} + 1*X_{81} + 2*X_{91} + 3*X_{101} + 2*X_{111} + 2*X_{121} + 1*X_{141} + 1*X_{151} + 1*X_{161} + 1*X_{171} + 1*X_{181} + 1*X_{191} + 1*X_{201} \leq 30$

$9*X_{12} + 5*X_{22} + 4*X_{32} + 3*X_{42} + 3*X_{52} + 3*X_{62} + 5*X_{72} + 1*X_{82} + 2*X_{92} + 3*X_{102} + 2*X_{112} + 2*X_{122} + 1*X_{142} + 1*X_{152} + 1*X_{162} + 1*X_{172} + 1*X_{182} + 1*X_{192} + 1*X_{202} \leq 20$

ISSUES AFFECTING THE INTEGRATION OF EMERGING INFORMATION TECHNOLOGIES INTO CORPORATE INFORMATION TECHNOLOGY STRATEGY: A DELPHI STUDY

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ABSTRACT

The accelerating evolutionary pace of technology creates a heretofore-unseen dilemma for the information technology executive charged with the responsibility of developing an IT strategy. Specifically, an executive who plans an IT strategy using only currently available commercial technologies must accept the prospect that some, or perhaps all, of the technologies may become obsolete prior to implementation. A potential remedy for the aforementioned problem exists in the form of emerging information technologies. By considering emerging information technologies as potential components of IT strategy, executives may be able to minimize the impact of the rate of technological evolution on IT strategy. This process requires the executive to evaluate technologies earlier in the product development life cycle. Accordingly, there are additional issues that executives must address with respect to emerging information technologies and IT strategy planning. This paper reports the findings of a four round web-based Delphi Study designed to elicit a cohesive set of issues that affect an IT executive's decision to integrate emerging information technologies into corporate IT strategy.

INTRODUCTION

In the competitive business arena that is the global marketplace, a strategy may be the single discriminating factor between the success or failure of an organization. Information technology executives recognize the importance of an effective organizational information technology strategy (Brancheau & Janz, 1996; Niederman et al., 1991). However, the rapid evolution of information technology (IT) injects an additional degree of complexity into the formulation and implementation of corporate IT strategy (Gordon, 2002; Low, 2001; Varon, 2000). Specifically, the innovation rate of IT has reached such a frenzied pace that organizations face the dilemma of planning a technology-based strategy with currently available commercial technologies that are often obsolete by the time of implementation (Benamati & Lederer, 2001; Davenport, 2001). Using emerging information technologies, strategists may diminish the evolutionary effects of technology on IT strategy. However, research suggests most technology executives charged with the responsibility of developing and implementing corporate information technology strategies do not employ plans that rely on emerging information technologies and therefore detrimentally affect the useful life of newly crafted strategies (Cegielski, 2001).

The research described herein utilized a web-based Delphi method to solicit, from information technology executives, a cohesive set of issues that significantly affect the integration of emerging information technologies into corporate technology strategy. Additionally, an online chat session with the participating executives provided a forum through which the practitioners were able to express additional qualitative sentiments regarding the adoption of emerging information technologies into corporate strategy.

The general implications of the current study are two-fold. First, the findings of the study provide significant insights for practitioners attempting to develop more timely information technology strategies. More importantly, the issues elicited during the Delphi rounds of the study offer an initial perspective from which researchers may populate decision models such as the Theory of Planned Behavior or the Theory of Reasoned Action to explain the adoption-decisions of IT executives regarding emerging information technologies.

INNOVATION DIFFUSION AND EMERGING INFORMATION TECHNOLOGIES

The most appropriate theoretical perspective from which to extend the current study is the sociological research domain of innovation diffusion. For this reason, the following sections include a brief overview of the research tradition of innovation diffusion.

An innovation is an idea, practice, or an object perceived as new by an individual (Rogers, 1995). It is important to note that it does not matter whether the idea, practice, or object is new by the measure of time that has lapsed since its discovery (Katz, 1961). The perception of newness by the potential adopter determines the reaction to the idea, practice, or object. Thus, if an individual perceives an idea, practice, or object, as new, it is innovation. Generalized knowledge regarding an innovation is one common measure of newness (Katz & Levin, 1959).

In many instances, innovation assumes the form of technology. Technology is a design for action that reduces the level of uncertainty in the cause and effect relationship involved in achieving a desired result (Rogers, 1995). Technology has two potential forms - hardware and software (Rogers, 1995). In innovation diffusion research, hardware and software have much more encompassing definitions that those definitions popularly employed in information systems research. Hardware is the tool that embodies the technology in physical form. Software is the information basis of the tool. Examples of hardware as technology, like the airplane or the television, are very common, as they manifest in tangible form. Technology embodied as software may be less obvious to casual observation. Political theories like Marxism and religious ideologies such as Calvinism are examples of technologies that are composed exclusively of information, and thus described in innovation diffusion research as software. Most often, technology is a combination of hardware and software. Because generalized information technology is the artifact of interest in the current study it is important to understand that both information technology hardware (i.e. workstations, routers, servers, printers) and information technology software (any coded program) are, in the broader constructs of innovation diffusion research, forms of hardware.

Emerging information technologies (EIT) represent a distinct category of IT innovation. For the purposes of this discussion, EITs are innovations that are in the early stages of development. Defining characteristics of EITs often include incomplete product standardization and limited availability (i.e. beta versions of software and prototypes of hardware). There are two distinct categories of emerging information technologies: 1) evolutionary extensions of existing technologies or 2) revolutionary new technologies, heretofore, unknown. Regardless of how an EIT is classified, the explicit business application of the EIT is the same: the capability of achieving a practical purpose more effectively or more efficiently than an existing technology. During the past decade, organizations have integrated a multitude of emerging information technologies into the ordinary course of business. Currently pervasive business applications of information technology such as e-mail, data warehousing, and client/server computing were, at one time, emerging information technologies.

CORPORATE STRATEGY AND INFORMATION TECHNOLOGY

Corporate IT strategy derives direction from the overall organizational strategy (Segars, Gover & Teng, 1998; King, 1988). Many organizations have well-developed IT strategies that complement the organizational strategy (Segars & Grover, 1998). However, most corporate IT strategist base future IT strategies upon currently available information technologies (egielski, 2001; Satish & Ritu, 1999). Simply stated, information technology executives focus on integrating today's commercially available technologies into tomorrow’s IT strategy. In doing so, most executives develop corporate IT strategies that dramatically lag behind the evolution of technology. To remedy the problem of dated IT strategy, IT executives should focus some attention on emerging information technologies. Examining EITs during strategy planning affords the IT executive the opportunity to anticipate tomorrow's business applications of IT today. The inclusions of EITs in corporate IT strategy planning results in the development of a proactive, forward-looking, IT strategy.

THE DELPHI METHOD

The qualitative nature of the current study dictated the use of a non-traditional information systems research methodology. Specifically, the current study utilized the Delphi Method, a survey research technique developed by the Rand Corporation in the early 1950s (Dalkey & Helmer, 1963). Because of the unique characteristics (Table 1) of the methodology, the Delphi technique is applicable for highly multi-dimensional research questions that deal with uncertainty in a domain of imperfect knowledge (Churchman & Schamblatt, 1965; Paliwoda, 1983). The objective of the technique is to achieve consensus among experts regarding a specific topic (Taylor & Meinhardt, 1985). In previous comparative analysis of group survey techniques, Riggs, (1983) and Rohrbaugh (1979) reported that the Delphi technique achieved a greater level of accuracy than other group consensus techniques.

Operationally, the application of the Delphi Method involves three phases: 1) the selection of expert panelist, 2) the collection of topic-relevant issues, and 3) the ranking of reported issues. The term "expert" is subjective therefore, a researcher must quantify, in some measurable terms, exactly what constitutes an expert for the purposes of the study. Of the Delphi studies published in MIS journals, researcher typically quantify experts based upon factors such as years of professional experience, job or position title, level of education, and professional certifications. To collect topic-relevant issues, the initial round of the Delphi questionnaire is open-ended (Delbecq, Van de Ven & Gustafson, 1975). The purpose of the first questionnaire round is to aggregate information for subsequent the ranking rounds of the study (Brancheau & Wetherbe, 1987). In the first round, the panel of experts contribute input that they feel pertinent to the focus question of the study (Nambisan & Agarwal, 1999). In the second round of the study, the panelists rank each of the issues from the first round (Paliwoda, 1983). From the data gathered in the second Delphi round, the study administrator scores the issues (typically using weighted average method) and redistributes the results to the panelist (Nambisan & Agarwal, 1999). In the third round, as well as any subsequent rounds of the study, the experts review the group rankings and to re-rank the issues given of the aggregated responses of the group. The process of ranking and re-ranking continues until the panelist achieve a consensus (Delbecq, Van de Ven & Gustafson, 1975).

Table 1: Characteristics of the Delphi Method

Characteristic	Description
Anonymity	By interacting only with the administrator, the panelist remain anonymous to one another.
Controlled feedback	Information is gathered and redistributed via the administrator.
Group response	Individuals contribute information to form a group response.
Expert opinion	Panelists are selected based on knowledge of the topic.
Reduced cost/ time	There is no need for the to arrange costly and time-consuming face to-face meetings

THE CURRENT STUDY

The current study utilized a Delphi process to aggregate and assess the relative importance of the issues that affect the integration of emerging information technologies into corporate information technology strategy. As part of the process, each potential panelist received an email solicitation for participation that included 1) the purpose of the study, 2) the definition of emerging information technologies advanced in the current study (EITs), and 3) three short summaries describing three different current emerging information technologies. Each of the three EITs used in the study is radically different - a telecommunications protocol, a programming language, and personal video technology. All three of the EITs chosen for the study meet the criteria of the definition of EIT advanced in this paper. Furthermore, the three EITs chosen for use in the study exhibit the property of *generalizability* - they are not technologies that are industry or application specific. For example, the telecommunications technology *Bluetooth* has as many potential applications in the automobile industry as it does in the financial services industry. Likewise, *XML* holds value for any organization with the desire to standardize web page applications, document transfer, or any number of other uses. Finally, virtual retinal display (VRD) is a technology that is applicable by end-users regardless of the industry or organization. The descriptions of the technologies selected for use in the current study, along with the aforementioned definition, provided the participants a common point of reference regarding EITs and the impact on IT strategy.

SUBJECTS

A review of Delphi studies published in MIS journals during the past 15 years revealed most studies utilize between 10 and 30 expert participants (Nambisan & Argarwal, 1996; Dekleva & Zupancic, 1996; Doke & Swanson, 1995; de Hann & Peters, 1993; Cougar, 1988). Only the SIM Delphi studies conducted by Brancheau et. al (1996, 1987) and a 1996 study by Malhota et al. included more than 50 participants throughout each round of the study. From the cursory analysis of previously published MIS Delphi studies, an initial number of 30 expert participants seemed appropriate for the current study. In order to obtain the desired number of participants, 212 CIOs from Fortune 1000 firms received the aforementioned email soliciting participation for the current study. Of the 212 individuals contacted, 75 individuals registered to participate in the current study.

Because of the diversity of the individuals who participated in the current study, it is important to report some associated information for the respondents. Geographically, there was representation from all major regions of the United States. Compared to 2000 census data, the South (46% of the respondents) was over-represented. This occurred mostly at the expense of the Midwest (11%). The West (19%) and Northeast (24%) were represented in proportions expected by their respective populations. The over-representation of the South is a function of the geographic proximity of the researcher conducting the current study. The Delphi respondents represented six industries. Information technology (25%) was the most represented industry followed by financial services (16%) and healthcare (16%). The employers of the respondents ranged in size from 3700 employees to over 65,000 employees. Seventy-eight percent of the respondents in the current study had 15 years of professional experience or more. Additionally, 81% of the respondents held the position of VP of Information Technology/Chief Information Officer/Chief Technology Officer. Finally, all respondents had an undergraduate degree and 35% had earned an advanced degree.

PARTICIPATION BY ROUND

The initial round of the study required the panelist to review the definition of EIT and read the three EIT summaries. Based on the definition and descriptions of the EITs, each participating executive submitted his or her perceptions of potential issues regarding the integration of each EIT into respective corporate strategy. In the first round, 37 of the 75 (49.33%) registered participants contributed 63 issues. After submitting comments regarding each of the three EITs, each executive classified the commonalities in his or her comments regarding the three EITs. Twenty-four of the original 63 issues were unique (Table 2). The unique issues provided the basis for the first ranking (round 2). In the second round of the study, 33 of the initial group of 75 (44%) registered participants ranked the issues (Table 3). All second round participants also participated in the first round of the study. Additionally, the computation of Kendall's Coefficient of Concordance was not significant therefore, a third round of the study was necessary to achieve a consensus.

Table 2: Unique Issues from Round One

1. Cost of the technology to deploy	2. Security of the technology
3. Ability to support the technology with current IT staff	4. Cost to maintain the technology
5. Acceptance of the technology by end-users	6. Current uses for the technology
7. Acceptance of technology by customers/clients	8. Reliability of the technology
9. Perceived future uses of the technology	10. Standardization of the technology
11. External support for technology	12. Use of technology by competitors
13. Commercial access to the technology	14. Training for users of technology
15 Compatibility with knowledge management practices	16. Performance aspects of technology
17. Potential measurable return on investment in technology	18. Technology development life cycle
19. Ability to integrate technology over time	
20. Integration of technology with organizations outside the firm	
21. Ability to gain competitive advantage through use of technology	
22. Ability to sustain competitive advantage using technology	
23. Compatibility of technology with current business operations	
24. Compatibility of technology with future business operations	

Table 3: Rank of Issues from Round Two		
Issue	Rank	% of Participants who Ranked the Issue Equal to The Group Rank
Ability to gain competitive advantage through the use of technology	1	48.48
Ability to sustain competitive advantage using technology	2	39.39
Security of the technology	3	33.33
Acceptance of technology by customers/clients	4	36.36
Current uses for the technology	5	48.48
Perceived future uses of the technology	6	51.52
Reliability of the technology	7	30.30
Performance aspects of technology	8	33.33
Compatibility of technology with current business operations	9	27.27
Compatibility of technology with future business operations	10	39.39
Cost to maintain the technology	11	42.42
Integration of the technology with organizations outside the firm	12	33.33
Compatibility with knowledge management practices	13	36.36
Cost of the technology to deploy	14	54.55
Acceptance of the technology by end-users	15	36.36
Standardization of the technology	16	69.70
Ability to support the technology with current IT staff	17	54.55
Commercial access to the technology	18	42.42
Training for users of technology	19	60.61
Ability to integrate technology over time	20	69.70
Potential measurable return on investment in technology	21	63.64
External support for technology	22	69.70
Use of technology by competitors	23	81.82
Technology development life cycle time	24	87.88

For the next round of the study, the same 33 executives again responded. The computation of Kendall's Coefficient of Concordance proved to be significant. Thus, the group achieved a consensus of the relative importance among the issues with respect to the integration of an emerging information technology into corporate IT strategy (Table 4). To improve the degree of consensus among the panel, each of the 75 registered participants received an email solicitation for a final ranking round (round 4). Thirty-one of the panelist responded to the final call for participation. All were participants in the previous three round of the study. Analyses of the fourth round data resulted in the desired outcome - a stronger degree of consensus among the panelists (Table 5). Figure 1 provides a graphical representation of the movement of the issues by round.

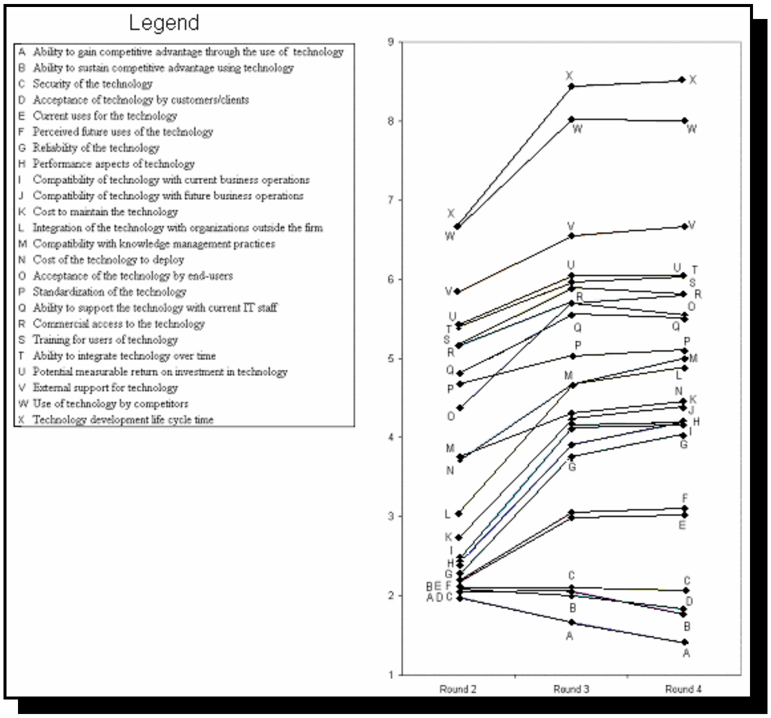
Table 4: Rank of Issues from Round Three

Issue	Round 2 Rank	Round 3 Rank	% of Participants who Ranked the Issue Equal to The Group Rank
Ability to gain competitive advantage through the use of technology	1	1	60.61
Ability to sustain competitive advantage using technology	2	2	48.48
Security of the technology	*3*	*4*	*51.52*
Acceptance of technology by customers/clients	*4*	*3*	*36.36*
Current uses for the technology	5	5	63.64
Perceived future uses of the technology	6	6	51.52
Reliability of the technology	7	7	57.58
Performance aspects of technology	8	8	63.64
Compatibility of technology with current business operations	9	9	45.45
Compatibility of technology with future business operations	10	10	63.64
Cost to maintain the technology	11	11	57.58
Integration of the technology with organizations outside the firm	*12*	*13*	*51.52*
Compatibility with knowledge management practices	*13*	*14*	*54.55*
Cost of the technology to deploy	*14*	*12*	*60.61*
Acceptance of the technology by end-users	*15*	*17*	*48.48*
Standardization of the technology	*16*	*15*	*66.67*
Ability to support the technology with current IT staff	*17*	*16*	*36.36*
Commercial access to the technology	18	18	51.52
Training for users of technology	19	19	48.48
Ability to integrate technology over time	20	20	69.70
Potential measurable return on investment in technology	21	21	75.76
External support for technology	22	22	75.76
Use of technology by competitors	23	23	87.88
Technology development life cycle time	24	24	90.91

Italic Denotes Change in Rank from Previous Round

Table 5: Rank of Issues from Round Four				
Issue	Round 3 Rank	Round 4 Rank	% of Experts Ranking Issue Equal to Group Rank	% of Experts Ranking Issue in Top Ten
Ability to gain competitive advantage through the use of technology	1	1	77.42	100.00
Ability to sustain competitive advantage using technology	2	2	61.29	100.00
Security of the technology	*4*	*3*	*54.84*	*96.55*
Acceptance of technology by customers/clients	*3*	*4*	*45.16*	*93.10*
Current uses for the technology	5	5	70.97	93.10
Perceived future uses of the technology	6	6	51.61	86.21
Reliability of the technology	7	7	54.84	72.41
Performance aspects of technology	8	8	61.29	65.52
Compatibility of technology with current business operations	9	9	64.52	55.17
Compatibility of technology with future business operations	10	10	74.19	51.72
Cost to maintain the technology	11	11	64.52	44.83
Integration of the technology with organizations outside the firm	13	13	64.52	48.28
Compatibility with knowledge management practices	14	14	61.29	44.83
Cost of the technology to deploy	12	12	64.52	37.93
Acceptance of the technology by end-users	17	17	58.06	27.59
Standardization of the technology	15	15	67.74	27.59
Ability to support the technology with current IT staff	16	16	51.61	17.24
Commercial access to the technology	18	18	58.06	13.79
Training for users of technology	19	19	54.84	3.45
Ability to integrate technology over time	20	20	64.52	6.90
Potential measurable return on investment in technology	21	21	74.19	0.00
External support for technology	22	22	70.97	0.00
Use of technology by competitors	23	23	90.32	0.00
Technology development life cycle time	24	23	93.55	0.00
Italics Denotes Change in Rank from Previous Round				

Figure 1: The Movement of the Issues Through the Delphi Rounds (by Mean rank Score)



EVALUATION OF GROUP CONSENSUS

Following the completion the fourth round of the study, the computation of Kendall's Coefficient of Concordance (W) revealed a consensus existed among the participants with respect to the round 4 rankings of the importance of the issues. Kendall's W is a measure designed to determine the degree to which a set of ranked scores agree (Sigel, 1956). A significant W indicates that the participants applied essentially the same standard in judging the importance of the issues and they are in consensus. The formula to compute W is:

$$W = \frac{s}{\frac{1}{12}k^2(N^3 - N)}$$

In this expression, s is sum of squares of the observed deviations from the mean of R_j, k is number of sets of the rankings, N is number of issues ranked, and $\frac{1}{12}k^2(N^3 - N)$ is the maximum possible sum of squared deviations, i.e., the sum s that would occur with perfect agreement among k rankings. For the final round rankings of the Delphi study, W was ($W = 0.6103$, $p < .001$) statistically significant.

Two additional estimates of consensus, the percentage of respondents whose issue rank matched the group rank and the percentage of respondents who ranked a given issue with a rank of 10 or higher (Table 5) provided an additional support to the assertion that the group is in accordance. Based on the Kendall's W and both of the aforementioned rank percentages, it is clear that the group achieved a consensus. Consequently, no additional Delphi rounds were necessary.

VALIDATION OF DELPHI FINDINGS

One limitation of the Delphi technique is the generalizability of the results. That is, the ranking of the issues is valid only with respect to the panel sampled. An exploratory survey utilizing the Delphi results provided a mechanism through which to validate the aforementioned findings The use of exploratory survey techniques are common in IS research (Pinsonneault & Kraemer, 1993), and one of the primary purposes of exploratory survey research is to define the dimensions of a construct within a population of interest. Given the exploratory nature of the current study, the utilization of an exploratory survey instrument is an appropriate research design by which to assess the Delphi findings.

The instrument developed served the single purpose of corroborating the findings of the Delphi process. Thus, the instrument did not solicit from the respondents additional issues that may affect the integration of EITs into corporate strategy. The data collected using the exploratory instrument provided a means to comparative analyze the findings of the Delphi rounds.

The membership of two international professional IT organizations, Society for Information Management (SIM) and the Association for Systems Management (ASM) participated in the exploratory survey round. One hundred and thirty-one members of the SIM and ASM groups received a solicitation for participation via email. Each individual received the same definition of EIT and technology examples presented to the Delphi participants. Jointly, 75 SIM and ASM members responded to a 24-question survey instrument. The instrument required the participants to rate, on a 7-point Likert scale, the importance the previously identified issues with respect to integration into corporate IT strategy. A comparative analysis of the results of round 4 of the Delphi process and the exploratory survey reveal a considerable level of agreement among both groups with respect to the ranking of the issues (Table 6). Specifically, 7 of the top 10 issues from the final Delphi round also appeared as top10 ten issues in the exploratory survey rankings. Additionally, the first two issues in both rankings coincided. Given the concordance between the two sets of rankings, it is reasonable to assert that some level of generalizability exist regarding the findings in the study. However, additional testing is required to validate the assertion.

Table 6: Comparison of Round 4 Delphi and Exploratory Survey Rankings		
Issues	Exploratory Survey Issue Rank	Round 4 Issue Rank
Ability to gain competitive advantage through the use of technology	*1*	*1*
Ability to sustain competitive advantage using technology	*2*	*2*
Security of the technology	14	3
Acceptance of technology by customers/clients	3	4
Current uses for the technology	4	5
Perceived future uses of the technology	5	6
Reliability of the technology	12	7
Performance aspects of technology	11	8
Compatibility of technology with current business operations	6	9
Compatibility of technology with future business operations	7	10
Cost to maintain the technology	13	11
Integration of the technology with organizations outside the firm	10	13
Compatibility with knowledge management practices	9	14
Cost of the technology to deploy	8	12
Acceptance of the technology by end-users	16	17
Standardization of the technology	*15*	*15*
Ability to support the technology with current IT staff	17	16
Commercial access to the technology	20	18
Training for users of technology	18	19
Ability to integrate technology over time	22	20
Potential measurable return on investment in technology	*21*	*21*
External support for technology	19	22
Use of technology by competitors	*23*	*23*
Technology development life cycle time	*24*	*24*
Italics denotes a matching Issue rank between both study groups		

ANALYSIS

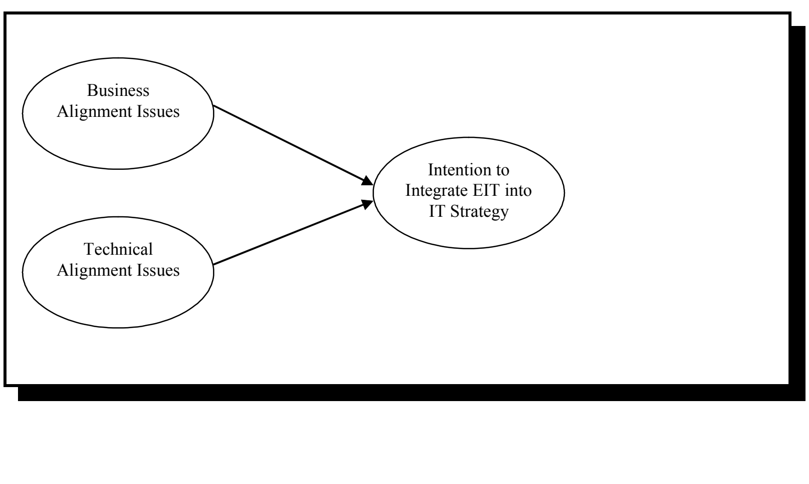
Qualitative feedback, obtained via an online chat session with the panel following the fourth Delphi round revealed that the overwhelming majority of the participating IT executives believe the

EIT integration decision stratifies into two separate but interrelated assessment areas: *business alignment issues* and *technical alignment issues* (Table 7). Interestingly, *alignment*, in numerous facets, appears as a key issue in IT strategy in several previous research studies (Table 7). According to a CIO from a global information technology firm whose sentiments were widely supported by the group, the two areas differ in that, "business issues address the general ways and means that a particular technology will support an organization's objectives" while technical alignment issues focus on "the nuts and bolts of a particular technology like compatibility with existing systems." Generally, the panel agreed that business alignment issues reflect concerns that are universal to all organizations - competitive advantage, customer relationship management, and organizational fit. Interestingly, the study participants defined all of these issues in qualitative assessment measures. Conversely, the technical alignment issues are firm specific and, as the study group described, tend to focus on very quantifiable aspect of a technology. According to the panelist, the consensus rankings of the top 10 issues illustrates a clear distinction between these two areas. The feedback from the panelist provides the foundation for the Emerging Information Technology Assessment Model (Figure 2)

Table 7: Stratification and Definition of EIT Integration Issues

Business Alignment Issues	Technical Alignment Issues
Gain/Sustain Competitive Advantage	Current/Future Uses of Technology
Internal/External Usefulness of Technology	Performance of Technology
Compatibility of Technology with Operations	Implementation Impact on Systems

Figure 2: Emerging Information Technology Assessment Model



CONCLUSION

The results of the current study imply that the process through which EITs become part of corporate information technology strategy may center upon two distinct factors. The first, business alignment, represents the leveragability of an emerging information technology within the general context of the organization. The dimensions of business alignment include the competitive advantage offered by an EIT, the current and future compatibilities of an EIT, as well as the general usability of an EIT. Typically, all firms contemplating integrating an EIT into IT strategy must consider these aspects of the technology regardless of organizational scope or nature. The other factor, technical alignment, includes more firm-specific "nuts and bolts" concerns of an EIT. Reliability, security, and performance are some of the issues that comprise the technical alignment factor. Each firm must addressed, in specific IT context, the appropriateness of an EIT as a component of IT strategy. Finally, although two constructs emerged in the current study, additional research is necessary to frame the factors into a cohesive decision criteria.

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PUBLISHING IN THE ORGANIZATIONAL SCIENCES: AN EXTENDED LITERATURE REVIEW ON THE DIMENSIONS AND ELEMENTS OF AN HYPOTHETICO-DEDUCTIVE SCIENTIFIC RESEARCH, AND SOME GUIDELINES ON "HOW" AND "WHEN" THEY SHOULD BE INTEGRATED

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ABSTRACT

In Publishing in the Organizational Sciences, professors Cummings, Frost, Taylor, Deetz, Nord, Staw, and Daft raised many important issues with respect to the actual publication system. Moreover, in two courses of my doctorate, I had the possibility to evaluate different qualitative and/or quantitative scientific research (most of them being hypothetico-deductive). This experience then led me to note several shortcomings pointed out in the literature. Inspired by these two contextual aspects, this paper aims to enhance hypothetico-deductive scientific research in organizational sciences. Its objective is twofold: (1) it carries out a synthesized extended literature review on the dimensions and elements that can be included into such the research; and (2) it suggests to authors some guidelines on "how" and "when" they should be integrated into them.
I think this paper can bring responses to some issues raised by professors Cummings, Frost, Taylor, Deetz, Nord, Staw, and Daft. From a theoretical point of view, it provides authors with a single very concise theoretical document that brings together and examines all of the actual dimensions and elements to conduct and describe hypothetico-deductive scientific research, whether they are quantitative, qualitative, or both. Further, it can even be used by editors and reviewers as a guide to evaluate hypothetico-deductive scientific research submitted by authors for publication. From a practical point of view, this paper brings a tool which can contribute to quality control of the production and dissemination of scientific knowledge in organizational sciences.

INTRODUCTION

Publication is a highly important activity of scholarly life. It allows, to a large extent, the dissemination of scientific knowledge. Thus, while remaining of a great integrity and fairness, it is essential for editors and reviewers to screen out low-quality works and force high standards in knowledge production among authors to maintain a high level of quality of published works and to protect the status of the profession. Moreover, it is extremely important of always keep in mind that the production of scientific knowledge must not be a race at the number of publications and that it is far better to put more emphasis upon publication quality rather than quantity (although the two are not mutually exclusive). In other words, even if scholarly life has often become an issue of "publish-or-perish", we must remain highly concerned about the quality of the production of scientific knowledge.

In my view, all scientific research, no matter it is quantitative, qualitative, or both, must be conducted with a high level of rigor and structure. By rigor and structure, I mean utilization of methods and models already established in existing literature, logical consistency between various steps of the research, strength of argumentation, as well as appropriate identification and coherence of the different parts of the article describing the research. But some will say that it is not quite to show rigor and structure in a scientific research, we must keep also place to the researcher's imagination and creativity. So I must answer that they are right. By imagination and creativity, I mean the enhancement of existing methods and models, the use of new methods and models, the logical presentation of new ideas, and the way to organize the ideas in a well-structured paper. In short, while showing a high level of rigor and structure to conduct and describe a scientific research, it is quite possible to keep also place to the researcher's imagination and creativity. And this paper is exactly oriented in this perspective.

The paper focuses on hypothetico-deductive scientific research (quantitative, qualitative, or both). More specifically, this one aims to enhance hypothetico-deductive scientific research in organizational sciences. Its objective is twofold: (1) it carries out a synthesized extended literature review on the dimensions and elements that can be included in such the research; and (2) it suggests to authors some guidelines on "how" and "when" they should be integrated into them. The paper is organized as following. First, I discuss the two contextual aspects which led me to write such a paper. Second, I conceptualize the dimensions and elements of an hypothetico-deductive scientific research. Third, throughout four relevant scenarios, including published research examples, I propose to researchers in organizational sciences some guidelines on "how" and "when" these dimensions and elements should be integrated into hypothetico-deductive scientific research. Finally, I bring my personal view about the theoretical and practical contribution of the article for the production and dissemination of scientific knowledge in organizational sciences.

CONTEXTUALIZATION

It is important here to emphasize the fact that two specific contextual aspects led me to write a paper that aims to enhance hypothetico-deductive scientific research in organizational sciences. On the one hand, we must be well aware that existing literature raises numerous issues with respect to the actual publication system. On the other hand, in two courses of my doctorate, I had the possibility to fulfill this interesting, enriching, and challenging task, but not always easy I must acknowledge, to evaluate different qualitative and/or quantitative scientific research (most of them being hypothetico-deductive). This experience then led me to note several shortcomings pointed out in the literature. Let me now describe in more detail these two contextual aspects.

In *Publishing in the Organizational Sciences*, professors Cummings, Frost, Taylor, Deetz, Nord, Staw, and Daft raised many important issues with regard to the actual publication system. Clearly, I will not stress here all of these issues. Rather, I will evocate only some of them which are closely linked to the object of this paper. First, as Cummings and Frost (1995a) point out, "Deciding what is false or even faked knowledge and distinguishing what is good scholarship from that which is the work of charlatans is not a simple matter" (p. 9). According to Frost and Taylor (1995), "Major sources of irritation and disaffection for dissatisfied readers tend to be the lack of quality in journal content, sterile journal material, and irrelevance of articles. Authors identify high rejection rates for their manuscripts (for example, four out of five submissions) […]. Journal editors sometimes express frustration with the poor quality of manuscripts and identify their own concerns as being high workloads […]. Reviewers are often dissatisfied with high workloads and relatively low extrinsic rewards" (pp. 14-15).

As Deetz (1995) says, "Publication has often become more of a credentialing process certifying expertise and assuring stature and appropriate club membership than a pursuit of socially important understanding" (p. 46). According to Deetz (1995), we can create systems and structures that aid the open pursuit of common understanding in changing our fundamental conceptions. In this perspective, he suggests to disconnect career reward structures from knowledge production activities, to eliminate traditional refereeing processes, and to focus on problems and provide answers in journal space rather than provide isolated expressions of claims. In Deetz's (1995) view of knowledge production, we must be able to approach major problems with consensual procedures and to have important innovative discussions that reveal genuine value differences and advance the role of professional knowledge in a more ideal democracy. Nord (1995) points out that in the Harvard-type case he used to organize an MBA class session in which the publishing-system-as-organization was presented as a case discussion to students, it is emphasized that the journals play a major role in the allocation of rewards and tenure in a field. "In fact, publication of at least several articles in the leading journals was described as a 'rite of passage' to permanent membership" (Nord, 1995, p. 65). Nord (1995) argues that the work of any field is to build theories, attract support from external constituents, and produce high quality information. He attributes the low status of organizational sciences to their failure to perform well on these tasks. Nord (1995) also discusses the virtues of the publication system as a control system that ensures quality, protects consumers from fraud, forces high standards among producers, and protects the status of the profession. On the other hand, Nord (1995) emphasizes the fact that the centralized control structure of the publication system is a source of both a lack of innovation and a lack of replication of ideas. According to Nord (1995), scientific journals have become too mechanistic, too much like palaces. He suggests the need for alternative organizational structures, such as adhocracies and tenets, to balance the existing ones.

Moreover, as Cummings and Frost (1995b) indicate, "It is not possible to talk for very long about publishing in the organizational sciences without addressing issues of relevance and rigor of what we publish in our field" (p. 79). According to Staw (1995), "Certainly what is relevant may not be rigorous, what is rigorous may not be relevant, and it is extraordinarily difficult for research to be high on both of these dimensions" (p. 85). Staw defines relevance as depicting the importance of a finding or idea for the advancement of knowledge. On the other hand, he raises a major problem with regard to confusion between a contribution to the literature and an advancement of knowledge. In fact, Staw (1995) says that "[…] we routinely judge the significance of a research paper by its contribution to the pile of studies already conducted and archived in the journals rather than its contribution to our understanding of organizations" (p. 86). As for the rigor, Staw (1995) defines it in terms of strength of inference made possible by a given research study. He also argues that strength in argumentation is central to a rigorous work. Furthermore, Staw (1995) raises an inevitable issue in publication, that is, the trade-off between normal science, which strives to achieve a set of replicated findings and clarified theoretical relationships, and creativity. From his point of view, it seems that publications are almost always biased toward normal science. "Our own creative ideas are criticized as shallow, ungrounded, inconsistent with existing theory, or just plain wrong. Our methods are often viewed by reviewers as deficient, flawed, and inappropriate when they are, of course, cleverly adapted to the new theory or type of data. As authors, we try to innovate, but are soundly rebuffed" (Staw, 1995, p. 93).

Finally, from the analysis of 111 manuscript reviews, Daft (1995) stresses the 11 more frequent problems that motivated his recommendation to editors to reject the manuscripts submitted by authors: (1) no theory; (2) concepts and operationalization not in alignment; (3) insufficient definition (theory); (4) insufficient rationale (design); (5) macrostructure (organization and flow); (6) amateur style and tone; (7) inadequate research design; (8) not relevant to the field; (9) overengineering; (10) conclusions not in alignment; and (11) cutting up the data.

As for the second aspect I evocated above, it is a lived experience in the setting of two courses of my doctorate whose the objective was to evaluate both quantitative and qualitative scientific research, most of them being hypothetico-deductive. Given in graduate school it is not very common for students to critically review the work of others (Rousseau, 1995), I am therefore fortunate, if not privileged, to have experienced this. In fact, in the first course, I evaluated only two quantitative research. As evaluation tool, the professor had suggested Davis and Cosenza's (1993) framework. I have then used this framework, but it seems to me very relevant to add it other essential dimensions and elements to evaluate a scientific research from all of its aspects.

Having greatly appreciated these first evaluations, I chose a second course related to student's development of a state-of-the-art knowledge of the more recent scientific works in the field of information systems (IS) and the introduction to critical review of articles. Given this time the professor had not suggested a specific evaluation tool, I have then decided to develop my own framework to this effect in integrating into it all of the actual dimensions and elements I found in key articles and best reference books on research in organizational sciences. Each week of the semester, we had to make a well-founded and realistic constructive critical evaluation of an article. Thus, to act as a reviewer in these two courses of my doctorate allows me to be confronted with several shortcomings pointed out in the literature.

Indeed, in my manuscript reviews, I often noted a ill-defined research objective, no research problem and question to justify the research need, a deficient or totally absent relevant literature review, no theoretical research model to guide the research or future research, no definition of the constructs and variables used in or emerged of the research, no hypotheses or propositions to test the research model, the weakness of the methodology used to conduct the research (for example, an inadequate research design, no sample and/or data collection description, no choice and justification of the data collection and/or data analysis methods, as well as no constructs measurements), no constructs validation, a deficient data analysis, an inadequate verification of the hypotheses or propositions, no answer to the research question, no comparison of the research findings with existing theory, no theoretical or practical research contribution to the advancement of scientific knowledge in the field involved, no research limits, no proposition of new research ideas to other researchers, no conclusions or conclusions not in alignment, as well as a poor research paper form (for example, illogical organization of the ideas and ill-structured sentences). We can see here that some shortcomings I observed in my manuscript reviews are similar to those noted previously by Daft (1995). Thus, to be confronted with these numerous shortcomings in the papers I reviewed in these two doctoral courses has been, in fact, the trigger element of the proposition of the dimensions and elements of an hypothetico-deductive scientific research I inventoried in the extended literature review carried out to develop my evaluation framework.

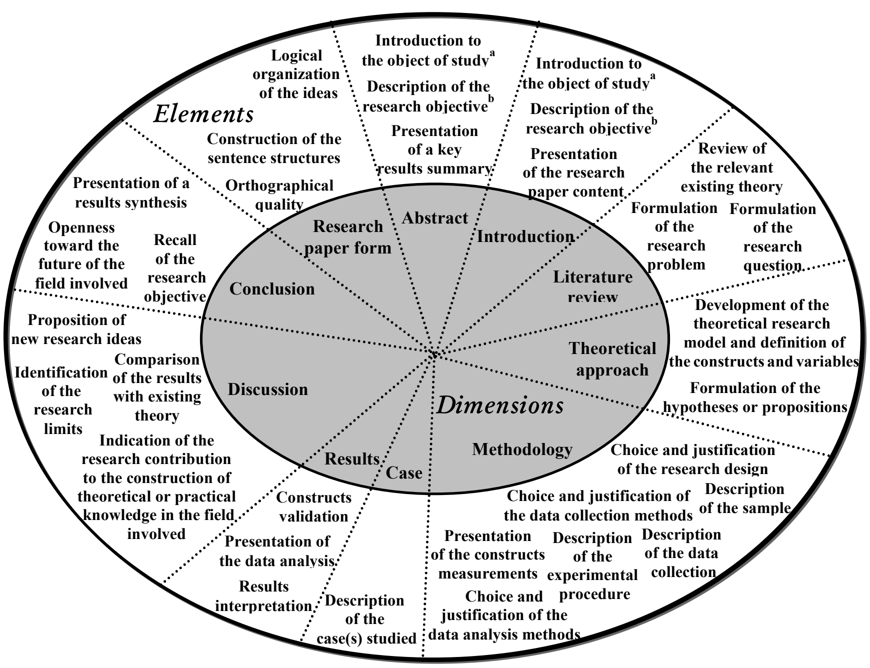
CONCEPTUALIZATION OF THE DIMENSIONS AND ELEMENTS OF AN HYPOTHETICO-DEDUCTIVE SCIENTIFIC RESEARCH

To conceptualize the dimensions and elements of an hypothetico-deductive scientific research, I took into account three scientific research paradigms: quantitative, qualitative, and multimethod (a combination of different elements of the first two). Gauthier (1992)[1] defines a scientific research paradigm as:

> *A set of implicit or explicit rules guiding the scientific research for some times in providing, from knowledge universally recognized, the ways to formulate the problems, to conduct the research, and to find the solutions (p. 568).*

Thus, each dimension and element inventoried in my extensive literature review applies to the three scientific research paradigms discussed above. And several elements might be included in different dimensions according to the researcher's style, the research paradigm (quantitative, qualitative, or both), the type of research (field experiment, laboratory experiment, field study, case study, longitudinal study, etc.), the research approach (data-driven[2], theory-driven[3], model-driven[4], etc.), and so on. The dimensions and elements that can be included into an hypothetico-deductive scientific research are diagramed in Figure 1. As shown in Figure 1, the diagram is articulated around 10 dimensions (see the internal circle) and 30 elements (see the external circle). In fact, the diagram is organized so that each dimension of the shaded internal circle can integrate one or several different elements of the external circle. It is fundamental to see the diagram depicted in Figure 1 just as a basic configuration of an hypothetico-deductive scientific research. Thus, according to the different factors related to the researcher and the research mentioned above, a researcher can include some elements in a certain dimension while another can include different elements in the same dimension, hence the shaded within the internal circle as well as the dashed lines at the boundaries of each area dimension-element of the diagram. Of course, the set of dimensions and elements diagramed in Figure 1 remains flexible and open to the addition of other ideas, dimensions, and elements. To better visualize the impact of the dimensions and elements of the diagram on scientific research, in the following subsections, I briefly present the dimensions whereas I provide the reader with a more in-depth discussion about the elements that can be integrated into them as well as their relevance in the research.

Figure 1. Dimensions and Elements of an Hypothetico-Deductive Scientific Research.



a, b: These elements are the same in the introduction dimension than in the abstract one, with the exception that they can be more developed in the introduction.

Dimensions of an Hypothetico-Deductive Scientific Research

Abstract

The first dimension of the diagram depicted in Figure 1 is the abstract. It is an important dimension because it provides very quickly the reader with an overall view of the research. We must recognize that it is really impossible to read all of the scientific research papers in our field and that we must then make some choices of reading. So the abstract is a precious tool to help us in these choices. In addition, it is an essential dimension to submit a paper for publication in most of the scientific journals and reviews, whether they are in print or electronic format on the Internet.

Introduction

The second dimension has to do with the introduction. It is really useful to put the reader in context and to provide him/her with a good insight into the discussion that follows. In effect, all document, no matter it is a research paper, a book, a doctoral thesis, a student's work, a business report, or others, must have an introduction. A document without introduction is like a good meal without appetizer: it lacks something!

Literature Review

Literature review is a very important dimension of the research. Its primary objective is to synthesize the relevant existing literature allowing to raise the research problem and question that require an investigation on the part of the researcher. Thus, a good review of the relevant existing theory allows the researcher to support his/her investigation on strong foundations.

Theoretical Approach

This fourth dimension of the diagram aims to present the theoretical approach to solve the problematic situation identified previously. In short, it is the conclusion of the conceptual work carried out until now by the researcher. It is in this extremely important part of the research that the researcher theoretically shows how he/she will get the response to his/her research question.

Methodology

Methodology is the fifth dimension. It is the core of the research, in fact. Unlike the previous dimension that shows the theoretical solution to the research problem raised by the researcher, this one shows the practical or pragmatic solution. It is in this part that is integrated and articulated the set of decisions to solve the problematic situation in a coherent way. Clearly, these decisions can differ on some points in accordance with the different factors related to the researcher and the research discussed previously, that is, the researcher's style, the research paradigm, the type of research, the research approach, and so on. What really matters, at this point, is to take the more effective decisions possible according to all of these factors and, especially, the fact that the theoretical approach, the results, and the discussion about the results must all correspond to this research operationalization. In brief, there are much factors at which the researcher must cope with in the methodology so that to take the more effective decisions possible to carry out the research.

Case

The case represents the sixth dimension. It should be noted that this dimension of an hypothetico-deductive scientific research is only appropriate for one type of research: case study research (quantitative, qualitative, or both). When the researcher is conducting a case study research, it is very important that he/she provides the reader with a good description of the case(s) studied so that the latter can better grasp the scope of the research.

Results

The next dimension has to do with the presentation of the research results. It is in this part of the research that the researcher gets the answer to his/her initial research question. Clearly, the more this procedure will be carefully performed, the more the answer to the research question will be precise and reliable. Overall, this procedure involves to analyse the data collected previously with some statistical and/or qualitative software, and to provide an appropriate, open, and fair interpretation of the results achieved.

Discussion

The eighth dimension of the diagram represented in Figure 1 is the discussion. Once the researcher has interpreted the research results, it is now relevant to have a good discussion about their impact in the scientific field concerned. In effect, this one aims to provide the reader with a more in-depth examination of some important aspects of the findings as well as a better view of both their effect and their scope at different levels of the field involved.

Conclusion

As for the ninth dimension, this one concerns the research conclusion. In this last part of the research, one could, for example, present to the reader a synthesis of both the results and the salient points of the research, as well as an anticipated view on the future of the scientific field involved. We must not forget that many readers read only the abstract, the introduction, and the conclusion of an article to get a quick overall view of its content. A good conclusion then becomes important. In short, it must be at the same time very concise and very consistent.

Research Paper Form

Finally, the tenth and last dimension relates to the research paper form. It should be noted that this dimension is not a part in itself of the research, but is rather related to the different ways to organize and write a research paper. The researcher can then include into it only relevant elements to the organization and writing of the article. The primary objective of a research paper is to communicate to other members of the scientific community how the researcher has conducted his/her research as well as the results achieved. Ideally, it must be logically organized, concise, clear, and well-written. In other words, it must be interesting and relatively easy to read for the reader. In this respect, as shown in Figure 1, I suggest three basic elements to integrate into this dimension, which reach, in my view, all of the most important aspects of a well-presented and well-written research paper: logical organization of the ideas, construction of the sentence structures, and orthographical quality. Yet another element one could also legitimately integrate into the research paper form is to make an attempt to get the discourse as exciting and living as possible.

Elements of an Hypothetico-Deductive Scientific Research

Introduction to the Object of Study

The first element of the diagram depicted in Figure 1 is the introduction to the object of study. So when the reader is beginning to read a research paper, the latter expects to know immediately the object of study or the general problem investigated by the researcher in order to assess the degree of relevance with his/her own research interests. To present the object of study in a scientific research, it could be relevant, for example, to answer this question: What is the problem to which I want to find a solution? In other respects, the diagram in Figure 1 shows that this element can be integrated into the abstract and the introduction of a research paper. Clearly, it is the same element, but it can be further discussed in the introduction than in the abstract so that the reader can better understand the problematic situation that requires an investigation on the part of the researcher. For example, in the introduction, it could be relevant to add the answer to the question: Why is it really important to treat this problem?

Description of the Research Objective

The description of the research objective represents the second element. As its name indicates, this very important element aims to inform the reader on the objective pursued by the researcher in his/her research. This description could be made, for example, in answering the following question: What I want to do or to show in this research? In other respects, as for the introduction to the object of study above, this element can be integrated in the abstract and the introduction of a research paper. Of course, it is the same element, but it can be further discussed in the introduction than in the abstract so that the reader can really see the work to be done through the same lens than the researcher. So to add to the understanding of the research objective in the introduction, one could, for example, answer this question: How can this objective be reached? Or this one: What is the scope of the research activities? Once the reader is well aware of the object of study and the research objective, then he/she can take a well-enlightened decision about whether he/she must going on in his/her reading.

Presentation of a Key Results Summary

The third element refers to the presentation of a key results summary. Such a summary provides the reader with an outline of the situation following the investigation. In this way, the reader having the same research interests can rapidly see whether these findings are either in the same or the opposite direction than previous research, or are shedding a new light on the object of study investigated by the researcher. And, on the other side, the reader having not the same research interests can then get an insight into what is happening in the field related to the object of study investigated by the researcher.

Presentation of the Research Paper Content

The fourth element of the diagram drawn in Figure 1 relates to the presentation of the research paper content. In fact, the goal of this element is merely to offer to the reader an outline of what is discussed in the research paper. One way to proceed could be, for example, to present each section that make up the latter. In short, at this point, the reader must be well aware of that he/she will learn in the paper.

Review of the Relevant Existing Theory

The review of the relevant existing theory is an extremely important element of a scientific research. In sum, it is essential to inquire the previous treatment of the object of study within its body of research. As Mace (1988) points out, the previous works are particularly useful when it is time to formulate the problem and to choose the verification strategy. By providing an orientation for what to look for, theory helps to determine which variables are relevant and which are not relevant (Pedhazur & Schmelkin, 1991). In addition, through problems and hypotheses derived from it, theory determines largely the type of research design, the analytic approach, and the results interpretation (Pedhazur & Schmelkin, 1991).

Formulation of the Research Problem

The next element of the diagram represented in Figure 1 has to do with the formulation of the research problem. Ideally, the review of the relevant existing theory on the object of study must allow the researcher to progress toward the formulation of a research problem. In fact, all scientific knowledge is fondamentally based upon a questioning process.According to Mace (1988), inscientificresearch, the only way to justify a work is to locate a gap in the previous works treating the same object of study and to fill this gap. This one becomes then the research problem. The interested reader can refer to Kerlinger (1986, pp. 16-17); the latter discusses three criteria to consider for the formulation of a research problem. We must not forget that an adequate expression of the research problem is one of the most important parts of the research (Kerlinger, 1986). Furthermore, a good part of the success or failure of the research effort is dependant on serious allowed to this initial step (Mace, 1988).

Formulation of the Research Question

The seventh element is the formulation of the research question from the research problem developed previously. The goal of this question is to guide and orient the research, to limit the area that will be covered by the researcher (d'Amboise & Audet, 1996). Therefore, it is important to ask the good question. In sum, we must formulate a relevant question, stated in clear and precise terms, and at which we will answer in taking into account our knowledge on the object of study and, above all, the available information [for the data collection] (Mace, 1988).

Development of the Theoretical Research Model and Definition of the Constructs and Variables

The eighth element concerns the representation, in form of model, of the theoretical solution allowing to solve the problematic situation and to define all of its components. Ideally, as stated before, the review of the relevant existing theory on the problematic situation allows us to discover constructs and variables that can be reused to provide a solution. We may also add our personal ideas. Thus, the function of the theoretical research model is to schematize all of these constructs, variables, and personal ideas in showing their relations (dependant, independant, mediator, or moderator). In addition, we can define them with existing literature and to bring into focus their role in the resolution of the research problem. On the other hand, it is important here to emphasize the fact that this element should be presented only after the data analysis in qualitative research and case study research. Indeed, as Daft (1995) argues, "In qualitative research, concepts and models should be defined at the end of the manuscript. The point of going out to observe organizations is to construct theory based upon the investigator's observations and interviews. The research goal is to end up with a well-defined set of constructs and a model that can be used to guide future research"

(p. 174). Similarly, in the case study research, "The difference is that the construct, its definition, and measurement often emerge from the analysis process itself rather than being specified a priori" (Eisenhardt, 1989, p. 542).

Formulation of the Hypotheses or Propositions

The next element relates to the formulation of the hypotheses or propositions. Sekaran (1992) defines an hypothesis in a scientific research as following:

> *An educated guess about a problem's solution... a logically conjectured relationship between two or more variables expressed in form of testable statements. These relationships are conjectured on the basis of the network of associations established in the theoretical framework formulated for the research study (quoted in d'Amboise & Audet, 1996, p. 27).*

According to Mace (1988), hypothesis is at the same time the result of the conceptualization and the starting point of the verification. It is the core foundation of all scientific work. Pedhazur and Schmelkin (1991) assess that "The guiding force of hypotheses in determining what to observe, what variables to relate, how to relate them, is undeniable" (p. 196). Kerlinger (1986) goes still more far while he argues that we must remember that there would be no science in any complete sense without hypotheses. In short, as for the research problem, hypothesis is a fundamental element of the research process. The interested reader can refer to Kerlinger (1986, p. 17); the latter discusses two essential criteria for the formulation of an hypothesis. On the other hand, in qualitative research, it is generally question of proposition rather than hypothesis. The researcher then will express his/her thoughts in form of research propositions, such the propositions playing the role of research hypotheses (d'Amboise & Audet, 1996). It should be noted that, as for the previous element, the formulation of the hypotheses or propositions should be presented only after the data analysis in qualitative research and case study research. In such the research, it is most of the time through the data analysis process that the themes, the constructs, the variables, and the relations between the variables, allowing the researcher to formulate hypotheses or propositions, begin to emerge.

Choice and Justification of the Research Design

The tenth element of the diagram depicted in Figure 1 is the choice and justification of the research design. In my view, to choose and justify a research design, it is to plan and describe the best way of investigation possible to get the answer to the research question while being at the same time the more rational possible for the necessary human, material, and financial resources. So it is a major element which can make all the difference in the success or failure of the research effort. In other respects, there is no consensus in the literature about the scope of a research design. For example, Kerlinger (1986) points out that "It includes an outline of what the investigator will do from writing the hypotheses and their operational implications to the final analysis of data" (p. 279).

And Pedhazur and Schmelkin (1991) argue that the research design is used differently by different authors or researchers. “Some use it ‘narrowly’, almost synonymously with the term ‘analysis’, whereas others use it ‘broadly’ to refer to all aspects of the research, including measurement, sampling, setting, data collection, analysis, and theoretical formulations” (Pedhazur & Schmelkin, 1991, p. 211). Like the supporters of the last part of the Pedhazur and Schmelkin’s quote above, I prefer to use the research design “broadly” in integrating it after the formulation of hypotheses or propositions, as shown in the basic configuration of the dimensions and elements of an hypothetico-deductive scientific research proposed in Figure 1. The interested reader can refer to Campbell and Stanley (1966, pp. 1-71), Contandriopoulos, Champagne, Potvin, Denis, and Boyle (1990, pp. 33-53), Kerlinger (1986, pp. 279-343), as well as Pedhazur and Schmelkin (1991, pp. 211-233 and pp. 250-317); these authors suggest a broad range of research design for experimental, quasi-experimental, and nonexperimental research, and discuss their internal and external validity.

Description of the Sample

The description of the sample represents the eleventh element. First, all research question defines a set of objects at which the research results should be applicable. This set can be more or less restricted, or more or less well-defined by the asked question (Contandriopoulos *et al*., 1990). It is, in fact, the target population. But the target population is most of the time too large to be studied in its whole. We must then choose a representative sample of the target population so that the research results can be the more generalized possible to this population. According to Kerlinger (1986), a representative sample has approximatively the same characteristics that the population relevant to the research question. “But we can never be sure; there is no guarantee” (Kerlinger, 1986, p. 111). It is therefore particularly important in a scientific research to carefully describe the selected sample so that the reader can well visualize the scope of the results on the target population. One could, for example, briefly introduce the target population and describe after in more detail the part of this population chosen for study.

Description of the Experimental Procedure

The next element of the diagram concerns the description of the experimental procedure. As its name indicates, this element is exclusively related to experimental research. And, more specifically, although this one might be included into a field experiment, it is rather associated to the laboratory experiment (see the different types of research addressed at the beginning of this section). The primary goal of this element is to provide the reader with a detailed description of the whole experimental procedure applied to the subjects of the research study. As Kerlinger (1986) says, “Research reports of laboratory experiments usually specify in detail how the manipulations were done and the means taken to control the environmental conditions under which they were done. By specifying exactly the conditions of the experiment, we reduce the risk that subjects may respond equivocally and thus introduce random variance into the experimental situation" (p. 367). As we can see in the last part of the Kerlinger's quote above, the latter emphasizes the importance to specify exactly the conditions of the experiment so that all of the subjects can perform this one in the same way to avoid as much as possible variance biases. Why make an attempt to avoid as much as possible variance between subjects in an experiment? I believe that the two most important reasons are the following: (1) so that the research results be representative and well-balanced with the experiment; and (2) so that the experimental procedure might be applied to other subjects, groups, situations, etc. and thus offer the possibility to increase the degree of generalizability (the external validity) of the results over time. Accordingly, not only it is very important to carefully describe the experimental procedure in the research paper, but it is essential, first, to well establish the conditions of the experiment so that all of the subjects can perform it in the same way. It is therefore a major element when the research conducted by the researcher is an experimental one. Taking into account that the subjects are already presented in the description of the sample above, one way to proceed to describe the experimental procedure could be, for example, to briefly present the environment where the experiment is done and specify after in more detail all of the conditions that it entails (material, training, tasks, tests, follow-up, etc.).

Choice and Justification of the Data Collection Methods

The thirteenth element has to do with the choice and justification of the data collection methods. It is another major step of the research process. So Mace (1988) stresses the fact that the quantity of information, its nature, and its degree of accessibility are as much conditions to the success or failure of the verification effort. Obviously, "[…] each approach has unique strengths and weaknesses, making it more or less suitable for studying certain phenomena, for specific purposes, in given settings, with specific resources, respondents, and the like" (Pedhazur & Schmelkin, 1991, p. 133). Consequently, it is the researcher's responsibility to choose the good approach and to justify this choice in accordance with the research context. Also, it is generally very interesting to combine two or more methods (quantitative, qualitative, or both) to get more details and thus enrich the information gathered on the object of study. The interested reader can refer to Gauthier (1992, pp. 251-514); the latter examines in-depth numerous data collection methods.

Description of the Data Collection

Although it is important to describe and justify the data collection methods, it is also important to describe the data collection itself. It is the fourteenth element. At this point, the reader expects to know how the data collection procedure took place and its results in order to better grasp the sense and value of the information gathered. For example, in a quantitative research using a questionnaire as data collection method, it would be interesting for the reader to know the number of distributed questionnaires, the respondents' status, the distribution time and means, the response rate, and so on. On the other hand, in a qualitative research using an interview as data collection method, it would be interesting for the reader to know the number of interviews, the interviewees' status, the time, place, and duration of the interviews, the language used, the number of interviewers, the way to grasp information (recordings, field notes, comments, etc.), and so on. Finally, when the research conducted is both quantitative and qualitative (the multimethod paradigm), one only has to bring together all of the components taken into account (among those suggested above, for example) in the description of the data collection.

Presentation of the Constructs Measurements

The fifteenth element refers to the presentation of the constructs measurements. Not only this step is considered as essential in the research process, but it is in the own researcher's interest to make it as carefully as possible given it is closely linked to the research results and to conclusions that can be drawn of them. Pedhazur and Schmelkin (1991) identify two major benefits of measurement: (1) it is appreciated when it is contrasted with alternative approaches to the description of or the differentiation among a set of objects with respect to a given aspect; and (2) it offers the possibility to apply the powerful tools of mathematics to the study of phenomena. Stevens (1951) defines construct measurement in the following terms:

> *"In its broadest sense, measurement is the assignment of numerals to objects or events according to rules" (quoted in Kerlinger 1986, p. 391).*

According to this definition, the point of the exercise is then to assign a quantitative sense to the constructs of the theoretical research model to confirm or infirm hypotheses. It is, in sum, to operationalize the constructs or the variables that make up the constructs on the basis of indicators and to attribute to each of them a scale of measurement (nominal, ordinal, interval, or ratio). The process is similar in qualitative research and case study research, that is, through constant comparison between data from diverse sources, the researcher builds evidence which measure the construct in each case (see Daft, 1995, p. 174; and Eisenhardt, 1989, pp. 541-542). On the other hand, constructs measurements should be presented only after the data analysis in qualitative research and case study research. As said before, it is most of the time through the data analysis process that the themes, the constructs, the variables, the relations between the variables, and the measures begin to emerge.

Choice and Justification of the Data Analysis Methods

The choice and justification of the data analysis methods represents the sixteenth element. Data analysis is a step of the primary importance in the research process. Hence, it is essential to choose the good analysis methods and to justify their choice with regard to reach the research objective. According to Contandriopoulos *et al*. (1990), when the researcher uses analysis techniques known and accepted as valid by the whole scientific community, he/she only has to briefly describe them. Otherwise, if he/she uses techniques less known, or known but in a less usual context, the researcher must further describe them. In this case, he/she should pay attention to the description so that this one not to be too much annoying and not to use a too much technical language. Ideally, the researcher must show the appropriateness of the selected analyses to answer the research question. The interested reader can refer to Creswell (1998, pp. 139-165), Miles and Huberman (1994, pp. 90-244), d'Amboise and Audet (1996, pp. 60-70), Hair, Anderson, Tatham, and Black (1995, pp. 78-670), Kerlinger (1986, pp. 125-276 and pp. 527-617), as well as Pedhazur and Schmelkin (1991, pp. 342-740); these authors examine in-depth numerous data analysis methods for qualitative (the first two quotes) and quantitative research (the last four quotes).

Description of the Case(s) Studied

The next element of the diagram depicted in Figure 1 has to do with the description of the case(s) studied. "The case study is a research strategy which focuses on understanding the dynamics present within single settings" (Eisenhardt, 1989, p. 534). "In brief, the case study allows an investigation to retain the holistic and meaningful characteristics of real-life events—such as individual lifecycles, organizational and managerial processes, neighborhood change, international relations, and the maturation of industries" (Yin, 1994, p. 3).

In a case study research, a clear and precise description of the case(s) studied allows the reader not only to better visualize the scope of the research, but also to better understand its results. Nevertheless, remember, there are some cases where anonymity is preferable. Yin (1994) emphasizes the two most important. "The most common rationale is that, when the case study has been on a controversial topic, anonymity serves to protect the real case and its real participants. A second reason is that the issuance of the final case report may affect the subsequent actions of those that were studied" (p. 143).

Constructs Validation

The constructs validation is the eighteenth element. It is an essential step to establish the reliability of the constructs measurements used by the researcher. According to Kerlinger (1986), it is probably the most important form of validity from the scientific research point of view. "Construct validation is concerned with validity of inferences about unobserved variables (the constructs) on the basis of observed variables (their presumed indicators)" (Pedhazur & Schmelkin, 1991, p. 52). In other respects, as for the constructs measurements, constructs validation should be presented only after the data analysis in qualitative research and case study research. In qualitative research, "To uncover the constructs, we use an iterative procedure—a succession of question-and-answer cycles—that entails examining a given set of cases and then refining or modifying those cases on the basis of subsequent ones (Huberman & Miles, 1994, p. 431). Traditionally, the resulting inferences are deemed 'valid' in the relaxed sense that they are probable, reasonable, or likely to be true" (Robinson, 1951, Znaniecki, 1934; quoted in Huberman & Miles, 1994, p. 431). Similarly, in the case study research "[…] researchers use multiple sources of evidence to build construct measures, which define the construct and distinguish it from other constructs. In effect, the researcher is attempting to establish construct validity" (Eisenhardt, 1989, p. 542). The interested reader can refer to Eisenhardt (1989, pp. 541-544), Huberman and Miles (1994, pp. 430-440), Kerlinger (1986, pp. 420-432), as well as Pedhazur and Schmelkin (1991, pp. 52-80); these authors describe several methods of constructs validation. Also, there are numerous software to help in this task, i.e., SPSS, SAS, PLS, LISREL, EQS, BMDP, QSR NVivo (NUD*IST Vivo), and ATLAS.ti.

Presentation of the Data Analysis

The nineteenth element concerns the presentation of the data analysis. Data analysis is a major step in the research process. It can make all the difference in a reliable or not reliable answer to the research question. Kerlinger (1986) suggests the following definition for the data analysis:

> *"Analysis means the categorizing, ordering, manipulating, and summarizing of data to obtain answers to research questions. The purpose of analysis is to reduce data to intelligible and interpretable form so that the relations of research problems can be studied and tested" (p. 125).*

On the other hand, we must be well aware that the data analysis is certainly one of the more difficult steps of the research process at the operational level (Mace, 1988). It is therefore essential to make this step as carefully as possible. Quantitative analysis is generally performed using statistical tools. On the other side, qualitative analysis can take different forms, for example grouping theme, pattern-matching, building explication, and content analysis. As for the constructs validation discussed previously, there are also numerous software to help us in the data analysis. But the point on which I want to stress here is the presentation of these analyses itself. In my view, it is essential in a scientific research to show all of the relevant analyses allowing to answer the research question, but no more so that the research paper not becomes too long because inappropriate analyses. Ideally, to present these analyses, one can use figures, tables, matrix, schemes, causal networks, graphics, and so on so that the reader can get the results in a visual way. For more details concerning different ways to analyze the data and present the results, the interested reader can refer to the same authors suggested above for the choice and justification of the data analysis methods.

Results Interpretation

Although it is very important to present all of the results leading to the answer to the research question, it is also very important to well interpret these results. It is the twentieth element of the diagram drawn in Figure 1. Results interpretation is another major step of the research process given it allows to better understand the meaning of the results and to provide a more complete answer to the research question. Thus, in his/her exercise of interpretation, the researcher will question himself/herself on the meaning of the results in the specific context of his/her research (d'Amboise & Audet, 1996). Overall, the exercise entails to carefully examine and describe all of the results presented previously in a visual way. If necessary, the researcher can also explain unexpected or outstanding results as well as the factors that can produced them. In addition, in a quantitative research, the latter can specify whether each hypothesis or proposition is confirmed or infirmed. As said earlier, in qualitative research and case study research, it is in this part of the research that the researcher should develop the research model, define the constructs and variables, formulate the hypotheses or propositions, and present the constructs measurements and validation. Finally, the researcher can indicate whether the research results answer or not his/her initial question.

Comparison of the Results with Existing Theory

The twenty-first element refers to the comparison of the research results with existing theory. To advance knowledge in a scientific field, it is essential to show the level of agreement or disagreement of the research results with those observed until now by other researchers on the same object of study. Obviously, we must take care to well support our discussion with the findings of the other researchers involved. As Kerlinger (1986) points out, "One compares the results and the inferences drawn from the data to theory and to other research results. One seeks the meaning and implications of research results within [existing theory], and their congruence or lack of congruence with the results of other researchers. More important, one compares results with the demands and expectations of theory" (p. 126). Similarly, Eisenhardt (1989) argues that "An essential feature of theory building is the comparison of the emergent concepts, theory, or hypotheses [or propositions] with the extant literature. This involves asking what is this similar to, what does it contradict, and why" (p. 544). In fact, is it not the ultimate aim of the scientist to discover better and yet always better theories able to overcome more and more hard tests (Popper, 1979)?

Indication of the Research Contribution to the Construction of Theoretical or Practical Knowledge in the Field Involved

The goal of the next element is to inform the reader on the research contribution to the construction of theoretical or practical knowledge in the scientific field involved. This can be briefly made using only one or two sentences and allows other researchers to quickly visualize the advancement of knowledge in the field. One could, for example, answer a question as this one: What this research brings to the field at the theoretical or practical level?

Identification of the Research Limits

The twenty-third element aims to identify the research limits. For example, to what extent the results can be generalized, the conceptual weaknesses, and the difficulties encountered by the researcher throughout the research. We must remember that all of these informations are very important for other researchers given they allow them, among other things, to be more aware of the scope of the research results and to benefit from this experience and thus decrease the risks to repeat the same errors in subsequent research. In sum, what really matters, at this point, is that the reader can clearly see all of the major aspects that limit the research and the scope of its findings, as well as what can be improved for future research.

Proposition of New Research Ideas

The proposition of new research ideas represents the twenty-fourth element of the diagram. When the researcher examined existing theory on the object of study, in different situations encountered throughout the research, in the results and conclusions drawn of them, and so on, the latter had numerous opportunities to have and/or identify new research ideas. It is then important that he/she communicates to other researchers these “fresh” ideas that can make the object of other very interesting and relevant research.

Recall of the Research Objective

The twenty-fifth element concerns the recall of the research objective. The goal here is to recall to the reader what the researcher would want to do in his/her research so that the former can see whether this objective has been reached or not. Clearly, the point of the exercise is not to repeat exactly what has been said on the research objective in the introduction of the article, but rather to briefly recall to the reader what the researcher would want to do.

Presentation of a Results Synthesis

At the end of a research paper, it is very relevant and interesting for the reader to get an overview of the findings. It is the twenty-sixth element of the diagram drawn in Figure 1. At the beginning of this results synthesis, one may also add some methodological elements such as the research design used, the number of participants, and the data collection and analysis methods. What really matters, at this point, is to provide the reader with a short summary of what the researcher has done in his/her research as well as the results achieved. Ideally, the research findings should be presented in more detail in the conclusion than in the abstract.

Openness Toward the Future of the Field Involved

The twenty-seventh element has to do with the openness toward the future of the field. In other words, the researcher makes an attempt to answer the question: What is likely to happen in the field in the long run? Thus, this particular element brings into focus the researcher's ability to act as a visionary. In sum, the researcher brings his/her personal view on some future tendencies or what it remains to be done in the scientific field concerned. Obviously, this view must be as realistic as possible, in the sense that it can be infered, in large measure, from the researcher's knowledge and experience in the field, as well as his/her research findings. As a result, it will be certainly very useful for the reader to have such an insight. This can be made using only a few sentences and allows other researchers to get a reflective view on the future of the field on the part of a colleague that was just actively working into it for a long time.

Logical Organization of the Ideas

As for the twenty-eighth element, this one refers to the logical organization of the ideas in the research paper. The logical organization of the ideas has to do with the macrostructure of the article. It is, in fact, to make sure that the different parts or microstructures of the article fit together into a coherent whole. As Daft (1995) says, "The theory has to be congruent with the method, the method with the results, the results with the discussion section, and all sections with each other" (p. 179). In other words, the research paper should flow logically in a straight line of thought without disgression. In other respects, one may also verify whether the style and tone used are appropriate, that is, a style and a tone that are not "amateur". According to Daft (1995), appropriate style and tone mean that the researcher masters very well what he/she is doing, that he/she avoids exaggeration, and that he/she is not justifying his/her research in criticizing the work of other researchers. These various aspects are really essential, in my view, to make a research paper interesting. Further, as Daft (1995) points out, "A good paper is extremely disciplined" (p. 170). In short, a paper with ill-organized ideas as well as amateur style and tone is not likely to attract the reader's attention.

Construction of the Sentences Structures and Orthographical Quality

Finally, the twenty-ninth and the thirtieth elements of the diagram depicted in Figure 1 are related to the construction of the sentence structures and the orthographical quality of the article. Clearly, a sentence that is relatively short, well-structured, and using appropriate words written without orthographical mistake will be certainly much more clear and easy to read for the reader than a ill-structured sentence written with orthographical mistakes. In brief, when we are writing a document, whether it is a research paper, a book, a doctoral thesis, a student's work, a business report, or others, we must always keep in mind that it is very unpleasant for the reader to read a ill-structured and/or ill-written document.

SOME GUIDELINES ON "HOW" AND "WHEN" INTEGRATE THE DIMENSIONS AND ELEMENTS INTO HYPOTHETICO-DEDUCTIVE SCIENTIFIC RESEARCH

In this section, I suggest to authors in organizational sciences some guidelines on "how" and "when" integrate the dimensions and elements discussed in the previous section into hypothetico-deductive scientific research throughout the development of four scenarios respectively related to field experiment, laboratory experiment, field study, and case study research, the core of the hypothetico-deductive scientific research, in fact. First, a scenario is described. Second, some dimensions and elements to include into the research in such a situation are proposed (the answer to the "when" question). Finally, some ways to integrate them into the research are suggested throughout relevant examples of published research papers (the answer to the "how" question). But before to begin to develop the scenarios, it should be noted that given, in my view, it is fundamental in all research paper to take care of its structure and writing, the research paper form dimension and the three elements that can be integrated into it (logical organization of the ideas, construction of the sentence structures, and orthographical quality) shown in Figure 1 occur implicitly into all of the scenarios that follow. Consequently, they are not taken into account in the scenarios.

Scenario 1

In the first scenario, you are a team of researchers that much like experimental research and you decided to conduct soon a theory-driven hypothetico-deductive field experiment to verify the impact of some information and communication technologies (ICT) on students' outcomes in distributed learning environments (taking for granted that an academic environment is also an organizational one). More specifically, you want to compare the outcomes of some groups of students using a certain ICT with other groups using a different ICT or not using an ICT.

What dimensions and elements should we include in such a situation?

I believe this situation entails that at least the following dimensions of the diagram represented in Figure 1 should be included in the research: the abstract, the introduction, the literature review, the theoretical approach, the methodology, the results, the discussion, as well as the conclusion. And, with the exception of the methodology in which the description of the experimental procedure is, in my view, rather optional (in effect, given that the experiment is not supposed to be of a great complexity in this situation, that is, just to compare groups of students using ICT in distributed learning environments, the description of this procedure can be made with those of the sample), all of the elements suggested for each of these dimensions in Figure 1 should be integrated into it.

How should we integrate these dimensions and elements in such a situation?

In a field experiment (A comparative study of distributed learning environments on learning outcomes) published in *Information Systems Research*[5] journal in 2002, which compares the learning outcomes of groups of students using two different group support systems (GSS) in distributed learning environments, Alavi, Marakas, and Yoo articulated their research as following. In the abstract, all of the elements shown in Figure 1 are present and addressed as proposed in this article. In the introduction, the authors have further discussed both the object of study and the research objective than in the abstract, as said before, but they have not presented the research paper content. Remember, it is important to present the research paper content so that the reader can have an outline of what is discussed in the article. The literature review is organized in form of background of collaborative distributed learning. The formulation of the research problem and question is included in the next section of the paper in which is also developed the research framework (or the theoretical approach as called in this article), that is, the theoretically supported hypotheses (in this case, there is no theoretical research model to schematize the constructs, however they are well-defined). Remember, when possible and relevant, it is important to graphically show to the reader the theoretical approach developed to answer the research question; this can lead the latter to a better understanding. The methodology describes only the executive development program studied by the authors. The subjects (or the sample as called in this paper) are presented in the next section. As the experimental procedure seems to be of a relatively high level of complexity in this research, it is then described in a specific section (following those of the subjects) in which the constructs measurements are also included. Although called differently (data analysis and results) than those in Figure 1 (results), the next dimension (or section) of the research paper integrates the same elements and these ones are addressed as indicated previously. In the last section, the results and their implications in the field are addressed. Overall, the authors discuss the same elements than those in Figure 1, however the discussion is rather organized around the implications of the findings in the field as well as their comparison with existing theory. The three other elements are quite slightly addressed. Finally, the article has not a formal conclusion. In fact, I think that, in the authors' mind, the last paragraph of the discussion is considered as a form of conclusion. Remember, no matter they are integrated at the end of the discussion or into the conclusion, the authors of a research paper should always provide the reader with a synthesis of the core research procedures and results, as well as an insight into what is coming in the field involved.

In another field experiment (Videoconferencing in distance education: A study of student perceptions in the lecture context) published in *Innovations in Education and Training International*[6] at the end of 1999, which compares the outcomes of groups of students using videoconferencing with other groups not using it, Fillion, Limayem, and Bouchard adopted practically the same research structure than those diagrammed in Figure 1. In the abstract, all of the elements shown in Figure 1 are present and discussed as proposed in this paper. In the introduction, the authors have further discussed both the object of study and the research objective than in the abstract, as mentioned earlier, but, as Alavi *et al*. (2002), they have not presented the research paper content. So the same comment made in the previous paragraph in this respect is also applicable here. The literature review of the article inquires the previous treatment of the object of study and leads to the formulation of the research problem and question as said before. In the next section, the theoretical approach is developed as suggested in this paper. Although quite differently organized, the methodology includes most of the elements shown in Figure 1. Indeed, the choice and justification of the research design, the choice and justification of the data collection methods, as well as the descriptions of the sample, the data collection, and the experimental procedure are presented in a same subsection of the methodology, which is called sample and data collection. The constructs measurements are presented in a second subsection of the methodology. On the other hand, the choice and justification of the data analysis methods are found in a subsection of the results called data analysis and results interpretation. Thus, with the exception that it also includes the choice and justification of the data analysis methods, the results dimension (or section) integrates the same elements and addresses them as indicated in this article. As for the discussion section, it is quite different. Called discussion and recommendations, this one compares the results with existing theory and provides students, professors, and educational institutions with a series of recommendations. The proposition of new research ideas is addressed in the conclusion of the paper. In addition, it includes the recall of the research objective and the presentation of a results synthesis. All of these elements are discussed as suggested in this article. In other respects, the identification of the research limits, the indication of the research contribution, as well as the openness toward the future of the field concerned are not present neither in the discussion nor in the conclusion. Remember, these elements are important to inform the reader on the scope of the research and its findings, and to provide him/her with an insight into what is coming in the field.

The interested reader can also refer to a field experiment conducted by Piccoli, Ahmad, and Ives (Web-based virtual learning environments: A research framework and a preliminary assessment of effectiveness in basic IT skills training) published in *MIS Quarterly*[7] at the end of 2001, which compares the outcomes of students in a traditional environment with those of other students in a virtual learning environment. And to those carried out by Webster and Hackley (Teaching effectiveness in technology-mediated distance learning) published in *Academy of Management Journal*[8] in 1997, which compares the outcomes and perceptions of the technology (videoconferencing) of students in different environments (face-to-face versus distance learning, full-motion video versus compressed video, etc.). As for the two field experiments reviewed above, in these ones, some dimensions and elements are called and/or articulated differently than suggested in Figure 1, but, overall, most of the dimensions and elements diagrammed in Figure 1 are present and addressed as indicated in this article.

Scenario 2

In the second scenario, you are a researcher who most of the time is part of a research team, but sometimes you also like to conduct your research in solo. You much like experimental research and you plan very seriously to carry out probably on the next month a theory-driven hypothetico-deductive laboratory experiment to investigate the effect of some independant variables (for example, decisional guidance, media used, and group cohesion) on the dependant ones (for example, students' outcomes, decision making, social presence, task participation, and group consensus) in making different comparisons of groups of students being exposed to an experimental procedure with other groups being not (as for the first scenario, it is taken for granted that an academic environment is also an organizational one).

What dimensions and elements should we include in such a situation?

I think this situation implies that at least the following dimensions of the diagram depicted in Figure 1 should be included in the research: the abstract, the introduction, the literature review, the theoretical approach, the methodology, the results, the discussion, as well as the conclusion. And all of the elements proposed for each of these dimensions in Figure 1 should be integrated into it.

How should we integrate these dimensions and elements in such a situation?

In a laboratory experiment (Providing decisional guidance for multicriteria decision making in groups) published in *Information Systems Research*[5] journal at the end of 2000, which compares groups of students using a group decision support system (GDSS) with decisional guidance with other groups using the same GDSS without decisional guidance, Limayem and DeSanctis articulated their research as following. In the abstract, all of the elements shown in Figure 1 are present and discussed as said previously. In the introduction, the authors have further discussed both the object of study and the research objective than in the abstract, as mentioned before, but they have not presented the research paper content. So the same comment made for the two previous articles examined above is also applicable here. The literature review inquires the previous treatment of the object of study and leads to the formulation of the research problem and question, as well as to the development of the theoretical research model. Called differently (implementing and testing the guidance concept) than those suggested in the diagram drawn in Figure 1 (methodology), the next dimension (or section) is also organized quite differently. Indeed, the authors included into this section the relevant theory leading to the implementation of the "guidance" concept as well as the hypotheses testing this one. They also integrated the descriptions of the sample, the data collection, and the experimental procedure, as well as the constructs measurements. In addition, the authors included into this section all of the elements of the results dimension and one of the discussion dimension shown in Figure 1, that is, the constructs validation, the presentation of the data analysis, the results interpretation, and the comparison of the results with existing theory. All of these elements are presented in several subsections so that, in the whole, the section is logically organized. Finally, the conclusion of the article includes the other elements of the discussion dimension and those of the conclusion dimension shown in Figure 1, and these ones are addressed in the same way as suggested in this paper, even in a better way.

The interested reader can also refer to a laboratory experiment conducted by Alavi (Computer-mediated collaborative learning: An empirical evaluation) published in *MIS Quarterly*[7] in 1994, which compares the outcomes of groups of students whose the collaborative learning is GDSS-supported with those of other groups whose the collaborative learning is non-GDSS supported. And to those carried out by Yoo and Alavi (Media and group cohesion: Relative influences on social presence, task participation, and group consensus) published in *MIS Quarterly*[7] at the end of 2001, which investigates the effect of the media and group cohesion on social presence, task participation, and group consensus of triads of students using audioconferencing versus other triads using desktop videoconferencing. As for the laboratory experiment examined above, in these ones, some dimensions and elements are called and/or organized differently than proposed in Figure 1, but, overall, most of the dimensions and elements diagrammed in Figure 1 are present and discussed as indicated previously.

Scenario 3

In the third scenario, you are a team of researchers that better like the field investigation. So since sometimes you and your colleague(s) are to organize a theory-driven field study in which you want to examine some aspects of the human communication both in face-to-face and with some media, as well as the relation between different factors that might have some influence on this communication and its outcomes (in this scenario, the research environment can be either academic or organizational).

What dimensions and elements should we include in such a situation?

In my view, this situation involves that at least the following dimensions of the diagram represented in Figure 1 should be included in the research: the abstract, the introduction, the literature review, the theoretical approach, the methodology, the results, the discussion, as well as the conclusion. And, with the exception of the methodology in which the description of the experimental procedure is not relevant in this case, all of the elements proposed for each of these dimensions in Figure 1 should be integrated into it.

How should we integrate these dimensions and elements in such a situation?

In a field study (Message equivocality, media selection, and manager performance: implications for information systems) published in *MIS Quarterly*[7] at the end of 1987, which examines the relationship between the content of managerial communication (middle- and upper-level) and media selection, Daft, Lengel, and Trevino organized their research as following. In the abstract, all of the elements proposed in Figure 1 are present and addressed as indicated previously. In the introduction, the authors have further discussed both the object of study and the research objective than in the abstract, as said earlier, but they have not presented the research paper content. So the same comment made for the previous articles reviewed is also applicable here. Really, several authors forget to provide the reader with an outline of what is discussed in the research paper when they write the introduction. Remember, it is important and it takes only a few lines. Although called differently (research problem) than those suggested in the diagram depicted in Figure 1 (literature review), the next dimension (or section) include the same elements, that is, a review of the relevant existing theory as well as the formulation of the research problem and question. Also called differently (theory development) than those shown in Figure 1 (theoretical approach), the next dimension (or section) discusses in-depth the theoretical foundations of the study. And the hypotheses are formulated in the next section. In the research method section (or the methodology as called in this article), with the exception of the experimental procedure (which is not relevant in a field study), the authors address all of the elements proposed in Figure 1 and as mentioned previously. The results are presented in a visual way and explained by the authors as indicated in this paper. Finally, in the next section called discussion and implications, they compare the results with existing theory and propose new research ideas, but the research limits and its contribution are not present. Remember, these two elements allow the reader to better visualize the scope of the research and its findings, as well as what it adds to the knowledge of the field. The research paper has no conclusion, but two of the three elements suggested in Figure 1 are integrated into the last paragraph of the discussion, that is, the recall of the research objective and the presentation of a results synthesis. Remember, it is also important to provide the reader with an insight into what is coming in the field involved.

The interested reader can also refer to a longitudinal field study carried out by Storck and Sproull (Through a glass darkly: What do people learn in videoconferences?) published in *Human Communication Research*[9] at the end of 1995, which examines the communication performance and quality of groups of students in a traditional environment or face-to-face versus other groups using videoconferencing. And to a field study conducted by Lengnick-Hall and Sanders (Designing effective learning systems for management education: Student roles, requisite variety, and practicing what we teach) published in *Academy of Management Journal*[8] in 1997, which investigates the relationship between some influencing factors, such as the transformation process and the student co-producer role, and the student products (personal effectiveness, management, and application of material) and reactions (satisfaction with results and process), also called the outcomes, in a high-variety communication system.

Scenario 4

In the fourth and last scenario, you are a team of two researchers that better like to investigate some particular cases. Also, you and your colleague are now ready to conduct a theory-driven case study research in which you want to examine the use and outcomes of computer-based systems (as for the previous scenario, the research environment can be either academic or organizational).

What dimensions and elements should we include in such a situation?

I believe this situation entails that at least the following dimensions of the diagram depicted in Figure 1 should be included in the research: the abstract, the introduction, the literature review, the theoretical approach, the methodology, the case, the results, the discussion, as well as the conclusion. And, with the exception of the methodology in which the description of the experimental procedure is not relevant here, all of the elements suggested for each of these dimensions in Figure 1 should be integrated into it.

How should we integrate these dimensions and elements in such a situation?

In a case study research (The information age confronts education: Case studies on electronic classrooms) published in *Information Systems Research*[5] journal at the beginning of 1993, which investigates the use and outcomes of computer-based instructional technology in the context of graduate business education, Leidner and Jarvenpaa articulated their research as following. In the abstract, all of the elements suggested in Figure 1 are present and addressed as indicated in this paper. In the introduction, the authors have further discussed both the object of study and the research objective than in the abstract, as mentioned earlier, but they have not presented the research paper content. So the same comment made for the previous articles reviewed is also applicable here. Curiously, none of the manuscripts examined in this section provides the reader with an outline of what is discussed into it at the end of its introduction. Should we removed this even so important element? Perhaps, but I do not think! For example, when an editor publishes a book that brings together a set of chapters or articles written by different authors, in the introduction of the book, he/she provides the reader with a valuable insight of what is addressed in each of these ones. The same holds in the case of a scientific journal or review. Further, after a quick verification in one of my pile of studies, it appears that numerous authors present their content in the introduction. The literature review, as called in the diagram drawn in Figure 1, is presented in two different sections, that is, a first section called information technology use in classrooms inquires the previous treatment of the object of study and a second called research questions develops the research problem and questions. In the research design and method section (or the methodology as called in this paper), with the exception of the experimental procedure (which is not relevant in a case study research), the authors discuss all of the elements suggested in Figure 1 and in the same way as proposed in this article, even in a better way. In addition, they describe the environment where each of the three cases are studied. The next section called results brings together the two ones proposed in Figure 1 (case and results) as well as an element of the discussion dimension, that is, the comparison of the results with existing theory. In brief, for each of the three cases studied, the authors describe the case, analyse the data, as well as discuss and compare the results with existing theory. Finally, in the next section called implications, future research, limitations, and conclusions, the authors address all of the other elements of the discussion shown in Figure 1 as well as those of the conclusion, and similarly as indicated in this article. More specifically, in a first subsection, they discuss the research implications and contribution, as well as the future research possibilities. It is also in this subsection that the authors develop a theoretical research model and formulate some assumptions to be tested in future research. We have therefore a good example here of what is suggested in this paper with regard to the fact that some elements should be presented only after the data analysis in qualitative research and case study research. Remember, in these two types of research, it is most of the time through the data analysis process that the themes, the constructs, the variables, the relations between the variables, and the measures begin to emerge. The next subsection addresses the research limits. As for the conclusion, this one is presented in the last subsection.

The interested reader can also refer to a case study research conducted by Goodman and Darr (Computer-aided systems and communities: Mechanisms for organizational learning in distributed environments) published in *MIS Quarterly*[7] at the end of 1998, which investigates the role of computer-based systems to enhance organizational learning in a formal electronic library and an informal community that uses a variety of communication technologies.

To summarize, we can see that, overall, the published research examples I chose to help me to suggest to authors in organizational sciences some guidelines on "how" and "when" integrate the dimensions and elements of the diagram depicted in Figure 1 into an hypothetico-deductive scientific research are very coherent with my own view. Clearly, some dimensions are called and/or articulated differently, and some elements are also called differently and/or integrated into different dimensions, but it is right (we just can call this "flexibility") and fit well with the view of an hypothetico-deductive scientific research I want to share in this article. In sum, it was exactly the goal of the exercise here to review different hypothetico-deductive research papers already published in some high-ranked scientific journals in order to verify whether the dimensions and elements included into them by their authors fit well with those I propose in this article. As a result, it seems they do so. Also, it is not surprising that these manuscripts had been published in high-ranked scientific journals. All are both theoretically and methodologically strong. And the theoretical principle stated previously concerning the logical organization of the ideas or the macrostructure of a research paper, that is, the theory has to be congruent with the method, the method with the results, the results with the discussion, and all sections with each other, is rigorously applied. In other words, each of these research papers flows logically in a straight line of thought without disgression. Hence we can conclude that they are assuredly “good” models to follow.

In the last section of the article, I bring my personal view about its theoretical and practical contribution for the organizational sciences community.

THEORETICAL AND PRACTICAL CONTRIBUTION OF THE PAPER

The synthesized extended literature review on the dimensions and elements that can be included into an hypothetico-deductive scientific research I carry out in this paper as well as the guidelines on “how” and “when” they should be integrated into it I suggest to authors allow us to see some very interesting theoretical and practical implications for knowledge production and dissemination in organizational sciences. Indeed, I think this paper can bring responses to some issues raised by professors Cummings, Frost, Taylor, Deetz, Nord, Staw, and Daft with respect to the actual publication system (see contextualization section).

From a theoretical perspective, the paper provides authors with a single very concise theoretical document that brings together and examines all of the actual dimensions and elements to conduct and describe hypothetico-deductive scientific research, whether they are quantitative, qualitative, or both. Further, it can even be used by editors and reviewers as a guide to evaluate hypothetico-deductive scientific research submitted by authors for publication. These different aspects can contribute: (1) to increase quality, relevance, and rigor of the works carried out by authors; (2) to decrease high workloads of editors and reviewers; (3) to progress toward a common understanding of the role of scientific knowledge in our societies, in the sense that to show rigor and structure to conduct and describe scientific research, as well as to focus on understanding organizational problems and provide answers in scientific journals are strongly urged; and (4) to promote innovation and creativity among authors, in the sense that they can add and/or modify, and/or replace some dimensions and/or elements of the research structure diagrammed in Figure 1, as well as bring new ideas to improve it (while remaining, of course, in a rigorous and structured research environment).

From a practical perspective, the paper brings a tool which can contribute to quality control. One knows how much essential is this aspect in production and dissemination of scientific knowledge. As Gibbons, Limoges, Nowotny, Schwartzman, Scott, and Trow (1994) point out, “[…] scientific and technological knowledge production systems depend heavily and inherently on quality control” (p. 65). In short, according to Gibbons *et al*. (1994),

> *“What counts as knowledge is, ..., to a large extent, determined by what scientists and technologists say shall count, and this involves, implicitly if not explicitly the norms governing the ways they produce knowledge. Not only do those claiming to produce scientific knowledge have to follow certain general methods, but they also must be trained in the appropriate procedures and techniques. To be funded, researchers must formulate the problems on which they want to work in specific ways recognizable to their colleagues, and they must be scrupulous in reporting their results to a*

community of their peers using prescribed modes of communication. Science is a highly structured set of activities involving a close interaction between technical and social norms" (p. 31).

On the basis of Gibbons *et al.*'s (1994) view of quality control above, one can anticipate that an increase in quality of the works carried out by authors should be likely translated by a proportional increase of their acceptance and publication rates in organizational sciences journals. Clearly, I do not think that there is only "one best way" to conduct and describe an hypothetico-deductive scientific research in organizational sciences and that what I suggest in this paper agree it perfectly. On the contrary, I just believe this paper can allow us to take "one step forward" not only toward a better quality of published works, but also toward a better quality of the works carried out by authors and submitted for publication. I even ask to editors, reviewers, and authors to think about the diagram drawn in Figure 1 and eventually propose new ideas, dimensions, and elements that can improve it.

CONCLUSION

The two main objectives of this paper were to carry out a synthesized extended literature review on the dimensions and elements of an hypothetico-deductive scientific research, and to propose to authors in organizational sciences some guidelines on "how" and "when" they should be integrated into it. As for all other sciences, research is fundamental in organizational sciences. It aims to the advancement of scientific knowledge in its different fields of activities. It is therefore our responsibility, as researchers, to looking for a constant improvement of the quality of our scientific research to continuously evolve toward a better understanding of the human and technological needs of our organizations, and thus promote their development and productivity. It is with this thought in mind that I wrote this article. Is my goal reached? I hope so! Finally, I just would like to recall to editors, reviewers, and authors that all suggestions allowing the enhancement of the hypothetico-deductive scientific research structure I suggest in Figure 1 in the future are welcome.

ENDNOTES

1. It should be noted that d'Amboise and Audet (1996), Contandriopoulos, Champagne, Potvin, Denis, and Boyle (1990), Gauthier (1992), as well as Mace (1988) are references to french scientific research books. So the french-english translation has therefore be made as rigorously and carefully as possible by the author of this article to keep authenticity and truthfulness of the theories of their authors.
2. Data from various sources (databases, data warehouses, reports, census, business directories, stock exchange, etc.) serve as starting point for the research. The research results are infered from these entry data.
3. Existing theory underlies the research. It allows to identify constructs and variables that can be reused to guide the research. These constructs and variables, and the links between them are usually illustrated in a logical model.

[4] A standardized domain model (organizational, decision making, financial, optimization, simulation, etc.), which may underly a methodology, is at the basis of the research. For example, at the organizational level, Checkland (1981) seeks to model organizations using the concept of a "soft system" and Eden and Ackermann (1998) focus on using cognitive or causal mapping (quoted in Morton, Ackermann & Belton, 2001).

[5] In the large-scale online survey conducted by Peffers and Ya, from october 2002 through january 2003, 1129 IS researchers ranked *Information Systems Research* journal first in the 10 top ranked journals, ranked by average weighted perceived value rating as outlets for IS research.

[6] *Innovations in Education and Training International* (now *Innovations in Education and Teaching International*) is essential reading for all practitioners and decision makers who want to stay informed about the developments in education and training. It is the official journal of the Staff and Educational Development Association. Retrieved September 8, 2003, from http://www.seda.ac.uk.

[7] In the large-scale online survey conducted by Peffers and Ya, from october 2002 through january 2003, 1129 IS researchers ranked *MIS Quarterly* journal second in the 10 top ranked journals, ranked by average weighted perceived value rating as outlets for IS research.

[8] In the large-scale online survey conducted by Peffers and Ya, from october 2002 through january 2003, 1129 IS researchers ranked *Academy of Management Journal* third in the 50 top ranked allied discipline research journals, ranked by average weighted perceived value rating as outlets for IS research.

[9] *Human Communication Research* is one of the official journals of the prestigiousInternationalCommunication Association. Retrieved September 8, 2003, from http://www.icahdq.org/. It is a top-ranked communication studies journal and one of the top two journals in the field of human communication.

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IMPROVING GOLF COURSE THROUGHPUT BY MODELING THE IMPACT OF RESTRICTING EARLY TEE TIMES TO FASTER GOLFERS

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ABSTRACT

A model-based decision support system (DSS) for operating and designing golf course systems is presented in this paper. The DSS is based on a simulation model that accurately represents the variability and interactions that impact pace of play on a golf course. Research shows the economic benefits of understanding the impact of policy and design on golf course play, specifically throughput (rounds played) and cycle time (round length). A specific policy, only allowing fast golfers to begin early in the day, was shown to improve both throughput and cycle time. A new statistic is proposed, the time handicap, which measures both a golfer and course's pace of play. The DSS model was developed using MS-Excel and @RISK, a Monte Carlo simulation package. Using MS-Excel offers a much greater degree of transferability and usability than traditional standalone discrete-event simulation software.

INTRODUCTION

The golf industry is big business. In 1999, golfers spent $16.3 billion on green fees (National Golf Foundation website, 2003). Because of the Tiger Woods effect on popularity, the number of golfers is increasing, creating the need for more courses. Over 400 new courses are being constructed per year (National Golf Foundation website, 2003). Golf courses, like most business operations, are designed and operated to be profitable. Many factors influence profitability. This paper focuses on improving profits by increasing throughput (the number of golfers playing golf per day) of a golf course. The approach used in this paper is unique in that we apply proven math-based modeling technology to model golf course daily throughput.

Daily golf course play is a stochastic system where random events (lost balls, weather, and poor shots) and interactions (waiting for the group in front of you) heavily impact the pace of play. Although complex, daily golf course operations are very similar to other complex systems such as:

A manufacturing plant where parts are moving from production process to process
A distribution network where transportation devices (trucks, boats, planes …) move from location to location
An emergency room at a hospital where patients wait for treatment

In all of these examples, performance is impacted by variability and interactions. However, these examples and other complex systems have been analyzed with math modeling. Therefore, a golf course system should be a candidate for math-based analysis.

A model-driven DSS that represents daily play at a golf course is beneficial for both designers and course managers. In both, qualitative measures and experience are the primary tools. Little empirical knowledge exists that provides the quantitative impact on throughput. For example, how much do the following impact throughput: fairway width, length of course, elevation changes, bunkers, green size …? Certainly, designers know that the above impact pace of play. However, quantifying the impact is much more difficult. One study has shown that the number of bunkers and the hilliness of the course did not influence revenues (Schmanske, 1999). Similarly, course managers have questions regarding throughput. How much do the following impact throughput: tee-time intervals, shotgun starts, group size (2, 3, 4, 5...), carts vs. walking …? Increasing throughput and controlling, or at least forecasting, cycle time are two of the most important factors in revenue management (Kimes, 2000).

Before proceeding, the first question to be addressed is 'Is there potential for math modeling to increase profits by improving throughput?' Consider a typical course with a $35 green fee, 12 hours of daily playing time, an average round taking 4.5 hours for a group of 4 golfers, and 144 busy golf days (weekends and holidays). Based on a 4.5 hour (270 minutes) round of golf, a group (on average) finishes a hole every 15 minutes. In a 12-hour day, 31 groups (124 golfers) complete a round of golf. A modest 10% improvement in round length (243 minutes vs. 270 minutes) yields a 16% increase in throughput (144 rounds/day vs. 124 rounds/day) and over $100,000 increase in annual revenue. Certainly, the potential exists.

This paper has three objectives. The first is to demonstrate a math-based model that accurately represents the daily play at a golf course that can be the basis for a design and operations improvement DSS. The second objective is presenting a specific analysis that shows a traditional dispatching rule, shortest processing time (SPT), commonly used in industry also improves throughput and cycle time in a golf course system. The third objective is introducing a new statistic for quantifying a golfer's ability to play fast: the time handicap.

To reach these objectives, we have represented golf course play with a math-based model. A model of systems allows studying the system without the consequences of experimenting on the actual system. The benefits are reduced time and costs and increased safety and creativity. If the model used only once to solve a problem, it has been a useful tool. If the model can be used again, in a changing environment, with several variables at the control of the user, the model is then a model-driven decision support system. The most used method for modeling systems with variability and interactions is discrete-event simulation (DES). In general, simulation refers to a broad collection of methods and applications to mimic the behavior of real systems. Simulation models can be physical or logical (mathematics).

DES is a venerable and well-defined methodology of operations research and many excellent explanatory texts exist (Hauge & Paige, 2001; Law & Kelton, 2000; Pritsker, 1995; Winston, 2001).

The methodology is particularly useful in evaluating interdependencies among random effects that may cause a serious degradation in performance even though the average performance characteristics of the system appear to be acceptable (Shapiro, 2001). Additionally, simulation models are intuitive, which is an important reason for their longtime and continuing application to complex systems. The literature review found one published article where simulation was applied to modeling golf course play (Kimes, 2002). In this model, waiting occurred only on the first tee. In a real system, many opportunities exist for waiting, and not all of them occur at the beginning, i.e., on the first tee box. Waiting can occur anywhere a group's pace is dictated by the group prior. Therefore waiting can occur on all 18 tee boxes and in the fairways. The study also assumed that rate of play was normally distributed, and a skewed distribution is more likely. The time study used to build the simulation was based on one course. A new time study would need to be done for each course you wanted to analyze.

MODELING METHODOLOGY

A golf group consists of individual golfers, usually ranging from 1 to 5. Once set, the number of golfers in a group does not change. On each hole, the group begins on the tee box and hits one at a time. The group moves towards the green once all golfers in the group have hit from the tee box. Some golfers move to the green more quickly than others depending on many factors. Having reached the green, each golfer finishes by putting (one at a time) his/her ball into the hole. Once all golfers in the group have finished putting, the group proceeds to the next hole.

The group's pace is dictated not only by its own processing time, but also by the group's immediate predecessor and the type of hole (par 3, 4, or 5). A group must wait for its predecessor to be out of the way. For example on a par 4 (or 5), a group cannot begin to hit from the tee box until its predecessor is sufficiently out of range to prevent injury by hitting someone. Because of the short distance of a par 3, a group cannot hit from the tee box until its predecessor is off the green. On par 4/5's a safe distance is between 225 and 300 yards. We define the point that allows the group behind to safely hit as a gate and refer to waiting for the group ahead to be out of the way as gate management. Using gate management eliminates having to model every shot from every golfer. Rather, we focus on the time to reach gates and be out of the way.

On the tee box and green, individual golfers hit one at a time. Therefore, for the group, the processing times are additive. In the fairway, the Rules of Golf dictate that the ball farthest from the hole is played first (United States Golf Association website, 2003). However, golfers proceed to their ball in parallel; consequently, processing times are not additive, and the slowest golfer dictates the group's pace of play. A golf course is a terminal system. It has a definite beginning and ending as a function of daylight. For terminal systems, performance is very dependent on the system's initial conditions. For a golf course, a slow group early in the day often spells disaster for the remainder of the day in terms on the rounds played (throughput) and round length (cycle time).

The golf course system was modeled using MS-Excel and @RISK, a MS-Excel add-in. Although not a standalone discrete-event simulation software, MS-Excel has an assortment of functions that are quite capable of modeling a gate-management system. The add-in, @RISK, provided a concise method for modeling different scenarios and maintaining statistics for analysis.

The best way to illustrate the gate management modeling logic is through an example. Consider the first hole at the beginning of the day. The first two groups are modeled. Group one has the first tee time (time = 0), and group two's tee time is six minutes later. Table 1 shows the processing times for each group. Note that this table does not show event times, only processing times. Since hitting from the tee box is a serial process, times are additive, and group one takes 150 seconds. Before group two can hit from the tee box, group one needs to be out of the way. We define a gate 300 yards from the tee box that group one must be through prior to group two hitting.

Table 1: Processing times for a Par 4

Group	Golfer	Time to tee-off	Time through gate	Time to green	Time to putt
1	1	60	110	70	70
	2	30	90	60	30
	3	20	100	200 (max)	10
	4	40	140 (max)	40	70
Group		150	140	200	180
2	5	40	100 (max)	40	30
	6	40	60	60	40
	7	60	70	70	50
	8	20	80	80 (max)	40
Group		160	100	80	160

The golfers in group one move to the gate at different speeds, and the slowest golfer (golfer 4 in this example) is out of the way in 140 seconds (after leaving the tee box). From this gate, golfers in group 1 proceed to the green. Golfer 3 takes the longest (200 seconds). Once on the green, putting time is additive; therefore, the total putting times is 180 seconds, and the group's total time to complete the hole is 670 seconds. Similar logic exists for group 2, except its pace is dictated not only by its tee time and processing time, but also by group 1's pace. Table 2 shows the event times. Group 2's tee time is six minutes after group 1. Since group 1 is through the gate at 290 seconds, group 2 does not need to wait for group 1 and begins to hit exactly at its tee time. However, group 2 is not as fortunate in the fairway. Group 2 takes 160 seconds to hit from the tee box and 100 seconds to reach the gate; therefore it is ready go through the gate at 620 seconds. However, it cannot get through the gate until 670 seconds because group 1 is still on the green. Therefore, group 2 waits in the fairway for 50 seconds. This delay does not prevent group 3 from hitting at its scheduled tee-time of 720 seconds; however, this can change as the day progresses. As often with queuing systems, once behind, it is very difficult to get back on schedule. For par 3 and 5 similar logic is needed, except par 3s have no fairway gate and par 5s can have two fairway gates.

Table 2: Event times for a Par 4

Group	Tee-time	Off tee-box	Through gate	To green	Off green
1	0	150	290	490	670
2	360	520	670	750	910

The modeling approach used is gate management. In simulation modeling, gate management refers to controlling the flow of work items. Gate management has been used to model Kanban systems and drum-buffer-rope scheduling (Hauge & Paige, 2001). For accurately representing to-gate times, data were collected by a class of Operations Management students as a data analysis exercise. Four different types of data (500+ values) were collected from five different local courses. Each type of data fit a triangular distribution. See table 3 for the type of data and triangular distributions values for the minimum, mode, and maximum. Note that the tee box and putting values are times (minutes), and the other values are rates (yards/minute). The rates allow transit times to be determined on any hole on any course by dividing the hole-specific distance by the randomly generated rate. For example, consider a golfer leaving the tee box on a 400-yard par 4 hole. Assume that the out of the way gate is 300 yards from the tee box. To determine how long it would take for the golfer to be out of the way, a triangular distribution is sampled to get a rate. Assume the rate sampled is 75 yards per minute. If so, the time to reach 300 yards would be 4 minutes.

Table 3: Data Values

Data Type	Description	Min	Mode	Max
Tee box time (minutes)	The time for an individual golfer to address and hit the ball on the tee box. No waiting time included.	0.3	0.77	1
Tee box to gate (yards/minute)	After leaving the tee box, an individual golfer's rate while reaching an arbitrary (but identified) gate in the fairway.	40	70	160
Gate to green (yards/minute)	From an arbitrary (but identified) gate in the fairway, an individual golfer's rate while reaching the green.	40	90	200
Putting time (minutes)	The time for an individual golfer to complete putting and leave the green.	0.23	1.05	1.5

A good decision support system separates input data from modeling logic; thus, developing a tool that can be applied to many different systems. Our model-driven DSS separates course data from the modeling logic. Therefore, if a new course is to be analyzed, only the input data must be modified. The modeling logic takes into account which hole is a par 3, 4, or 5 and represents the gate management system accordingly. The input data structure used in this research is shown in Table 4. The first hole is a par 5. The first fairway gate is 250 yards from the tee box. The next fairway gate is 200 yards from the first fairway gate. The green is 50 yards from the second fairway gate, and the second hole's tee box is 50 yards from the first green. The second hole is a par 4; therefore, it does not have a second fairway gate. The third hole is a par 3; therefore, it does not have any fairway gates. Model assumptions are given in Table 5.

Table 4: Input Data

Hole	Par	Distance	To Gate 1	To Gate 2	To Green	To Next Hole
1	5	500	250	200	50	50
2	4	440	250	0	190	50
3	3	160	0	0	160	50
4	4	370	250	0	120	50
5	5	500	250	200	50	50
6	4	420	250	0	170	50
7	4	350	250	0	100	50
8	3	200	0	0	200	50
9	4	370	250	0	120	50
10	4	440	250	0	190	50
11	5	520	250	200	70	50
12	4	390	250	0	140	50
13	4	340	250	0	90	50
14	3	170	0	0	170	50
15	5	560	250	200	110	50
16	4	330	250	0	80	50
17	3	200	0	0	200	50
18	4	370	250	0	120	50

Although not modeled in this research, substantial opportunities exist for incorporating the assumptions as modeling parameters in subsequent research.

Table 5: Model Assumptions	
1.	Four golfers per group.
2.	No play-through logic (same group order throughout the round).
3.	Gates are hole-specific, not golfer-specific.
4.	No golfer designation except quantity (golfers/group). Carts/walking, fast/slow, good/bad, straight/erratic, long/short … are not included.
5.	No course designation except par and distance. Course difficulty, water, bunkers, rough height, elevation changes … are not modeled.
6.	No specific dollar values are modeled. We assume that daily operating costs are fixed are only marginally increased if daily throughput is increased. Therefore, we assume that increasing the rounds played not only increases daily revenue, but daily profits.

Validation, determining that the model accurately represents the real system, relied primarily on experience and expert judgment. Avid, if not talented golfers, the authors have a wealth of experience of how long a round can be played without waiting as a single or in a group. Results of a no-waiting analysis accurately depicted the authors' experiences and well established expectations. Similarly, the modeling of a busy course accurately reflected upwards of 5 hours for a weekend round of golf.

ANALYSIS OF RESTRICTING EARLY TEE TIMES FOR FASTER GOLFERS

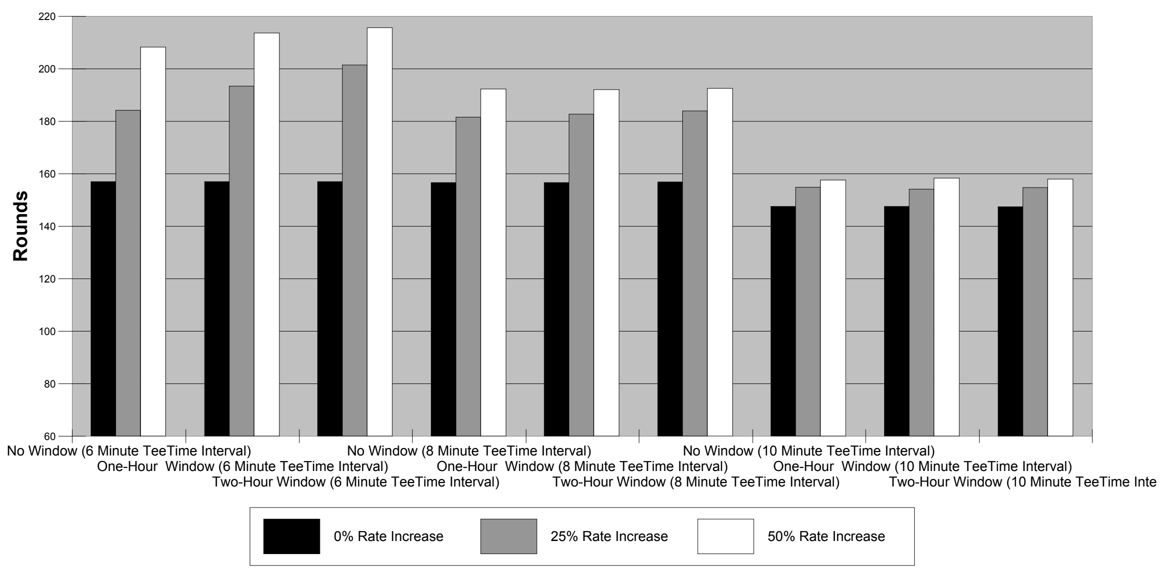
A golf course is a terminal system. It has a definite beginning and ending as a function of daylight. For terminal systems, performance is very dependent on the system's initial conditions. For a golf course, a slow group early in the day often spells disaster for the remainder of the day in terms on the rounds played (throughput) and round length (cycle time). To prevent this, we tested the impact of restricting early times to faster golfers. This approach is taken from manufacturing system design research that used the shortest processing time (SPT) dispatching rule (Johnson, 1954; Lawrence & Barman, 1989) for system improvement.

A three-factor (three levels per factor) experiment was designed. Factor A defined the speed of a fast golfer as a percentage increase (0%, 25%, and 50%) of the base times/rates shown in Table 3. Factor B defined the length of the time (hours) from the beginning of the day that only allowed fast golfers to begin their round (none, 1, and 2). Factor C is the tee time interval (6 minutes, 8 minutes, and 10 minutes). Table 6 summarizes the factors and level values. Each trial was a 500-day simulation. Since the system is terminal, no warm up period was required. Figures 1 and 2 show the 27 average daily rounds played and round length, respectively.

In aggregate, both Figure 1 and Figure 2 provide intuitive results. Moving from left to right, tee time intervals move from 6 minutes to 10 minutes. Shorter time intervals increase throughput (rounds played) and cycle time (round length). As the interval lengthen, rounds played and round length decrease. Within each group of three, fast golfers rate increase from 0% to 50%. As expected, higher rates increase the number of rounds played and reduce the round length.

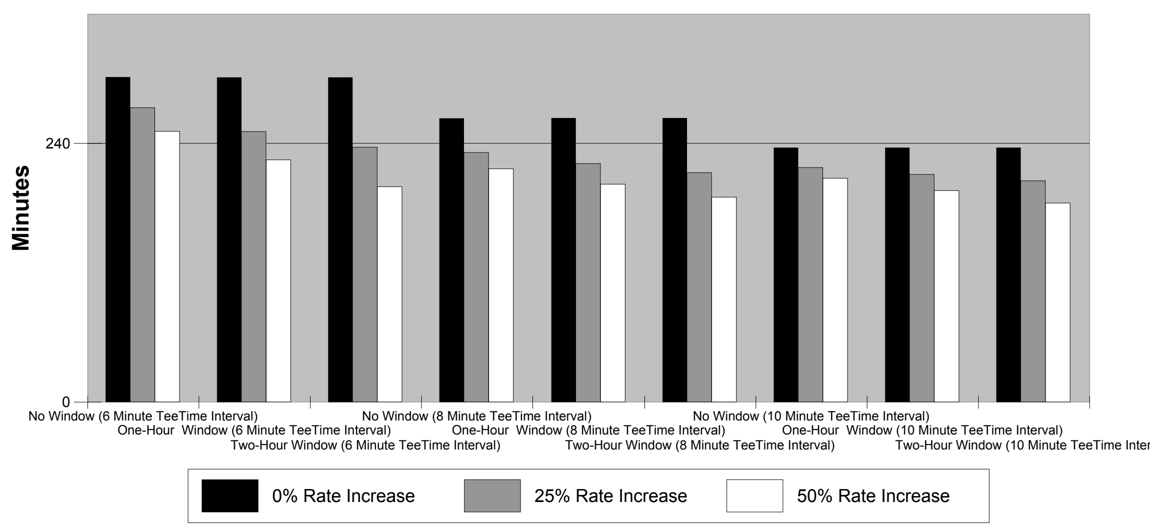
Table 6 Experimental Design Factors and Levels			
Factor	Level 1	Level 2	Level 3
A: Fast golfer speed (% increase in base speed)	0	0.25	0.5
B: Beginning of the day time window designated only for fast golfers (hours)	None	1	2
C: Tee time interval (minutes)	6	8	10

Figure 1. Rounds Played Per Day



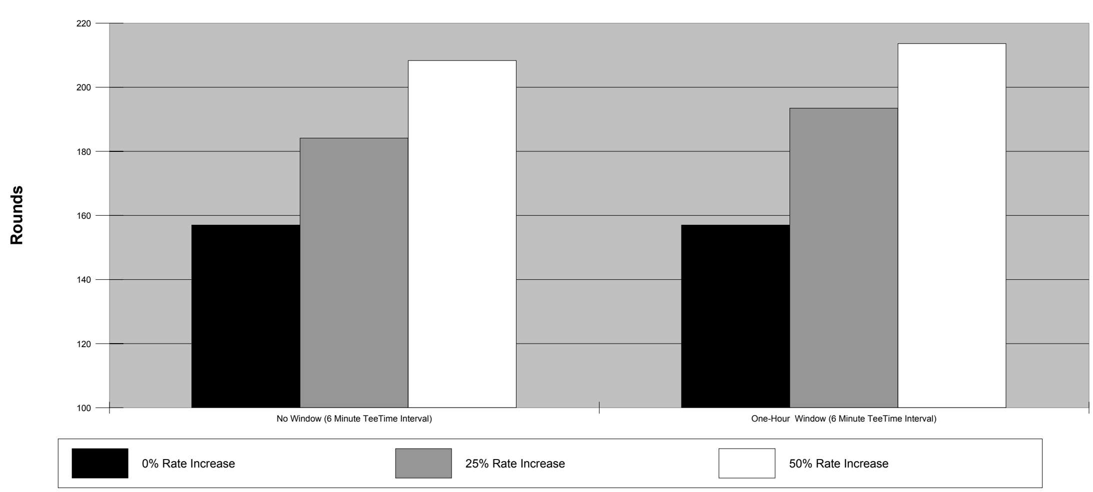
As we explore further, we see that the impact of a time window allowing only fast golfers to begin is the largest for a congested course (6 minute tee-time intervals) and provides minimal benefits for non-congested courses (10 minute tee-time intervals). Figures 3 and 4 highlight the circled areas from Figures 1 and 2, respectively. In Figure 3, the base case (no windows and no fast golfers) shows that the course averaged 157 rounds per day. However, if fast golfers could be identified and provided a one-hour time window that restricted the course to fast golfers, the average increased to 193 rounds per day (23% improvement) for golfers 25% faster and 214 rounds per day (36% improvement) for golfers 50% faster. For a 500-day simulation, the 90% confidence interval on average rounds played per year is the mean ± 3 rounds; therefore, the improvement is statistically significant.

Figure 2. Round Length (Minutes)



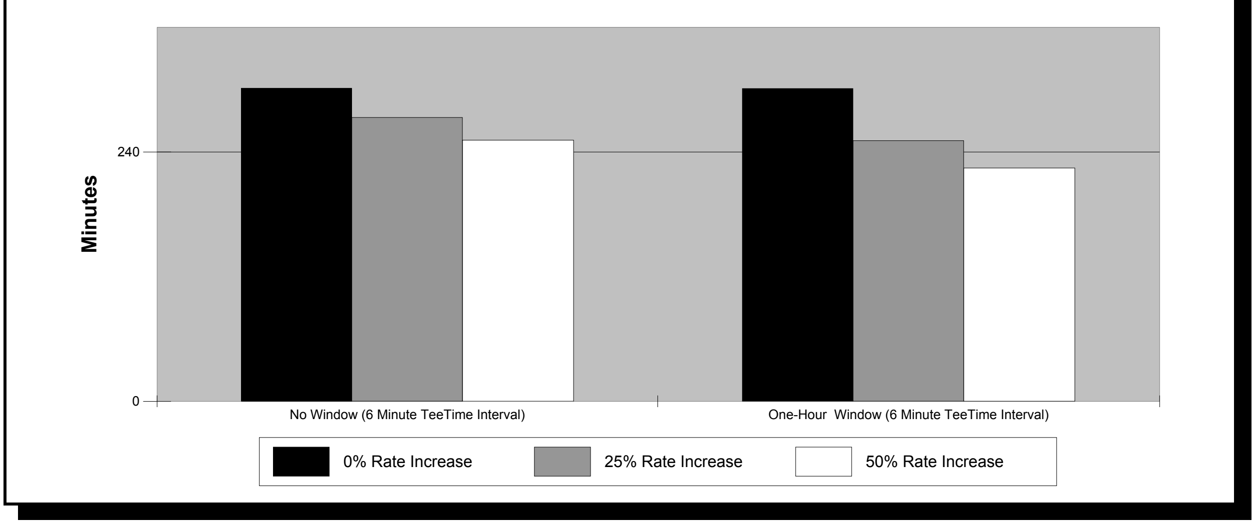
Similarly, Figure 4 shows a reduction in round length from 301 minutes to 251 minutes (17% improvement) for golfers 25% faster and 225 minutes for golfers 50% faster (25% improvement). For a 500-day simulation, the 90% confidence interval on average round length is the mean ± 5 minutes; therefore, the improvement is also statistically significant.

Figure 3. Rounds Played Per Day



The significance of this analysis is that improvements in the revenue-generating ability of a golf course exist without modifying the green fee structure, but by improving operations management.

Figure 4. Round Length (Minutes)



INTRODUCING A MEASURE OF A GOLFER'S PACE OF PLAY: THE TIME HANDICAP

To insure that those beginning early in the day not delay those following, course managers have several options. One is simply communicating the importance of a quick pace through signs and quick speeches prior to beginning a round. Another is having the course marshal continually monitor the early groups' progress and pushing them to move quickly. A method we propose is using a golfer's time handicap as a restriction on those who can begin early in the day. Analogous to a golfer's scoring handicap that measures a golfer's scoring ability, the time handicap measures an individual golfer's ability to play quickly. The time handicap could also be applied to individual golf courses, as well as golfers.

Although nonexistent, consider its implications if a time handicap did exist. First, popular public courses, i.e., Pebble Beach, would have a quick method for allocating tee times that would improve profitability without modifying how much to charge in green fees. Secondly, time handicaps would provide the golfing industry a measure of the pace of play, which is a requirement for system improvement (Rath and Strong Management Consultants, 2002). Courses with notorious slow play will be punished, and courses that move golfers through quickly will be rewarded. Golfers want to play immaculately groomed courses, but a beautiful course that takes six hours to complete is inferior to the beautiful course that guarantees a four-hour round! Finally, the act of measuring often provides system improvement. A golfer wants to improve his scoring handicap. We believe a golfer would also want to improve his time handicap. Systemic improvement of the time handicap would benefit all those involved.

The time handicap formula would be similar to the United States Golf Association (USGA) Handicap System's™ (United States Golf Association website, 2003):

> *The purpose of the USGA Handicap System™ is to make the game of golf more enjoyable by enabling golfers of differing abilities to compete on an equitable basis. The System provides fair Course Handicaps™ for players regardless of ability, and adjusts a player's Handicap Index™ up or down as one's game changes. At the same time, it disregards high scores that bear little relation to the player's potential ability and promotes continuity by making handicaps continuous from one playing season or year to the next. A USGA Handicap Index is useful for all forms of play. A basic premise underlies the USGA Handicap System, namely that every player will try to make the best score at each hole in every round, regardless of where the round is played, and that the player will post every acceptable round for peer review.*
>
> *A USGA Handicap Index compares a player's scoring ability to the scoring ability of an expert amateur on a course of standard difficulty. A player posts scores along with the appropriate USGA Ratings to make up the scoring record. A Handicap Index is computed from no more than 20 scores plus eligible Tournament Scores in the scoring record. It reflects the player's potential because it is based upon the best scores posted for a given number of rounds, ideally the best 10 of the last 20 rounds.*

Mathematically, the Handicap Index™ is a function of the golfer's recent scoring history, course difficulty, and tee boxes used. A time handicap formula would need to be a function of the golfer's recent round length history, courses played characteristics (difficulty, course length, round length), group characteristics (number in group, walking/riding/combination), and the time of day that the round begins. Currently, no formula exists. Subsequent research is required.

CONCLUSIONS AND FUTURE RESEARCH

The significance of this analysis is that improvements in the revenue-generating ability of a golf course exist without modifying the green fee structure, but by improving operations management. In the past, little effort has been devoted to modeling a golf course system as a complex system impacted by variability and interaction. The DSS model was developed using MS-Excel and @RISK, a Monte Carlo simulation package. Using MS-Excel offers a much greater degree of transferability and usability than traditional standalone discrete-event simulation software. Future research is plentiful. For example, more detailed data would allow additional golfer and course characteristics to be evaluated; thus providing both course managers and designers feedback on policy and design decisions.

Obviously, implementation is another matter. Golf is a social system steeped in tradition and slow to change. However, demonstrable revenue-generating opportunities are not ignored in business, even in golf.

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THE IMPACT OF PROCESS STANDARDIZATION AND TASK UNCERTAINTY ON CREATIVITY IN GSS ENVIRONMENTS

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ABSTRACT

This paper discusses the links between task complexity, group process structure and creativity in GSS environment. The type of standardization of the group process mediates the strength of the impact that groupware has on group creativity. Group creativity was found to increase when the group process is less restrictive. Greater levels of task uncertainty were found to lead to more creative solutions.

INTRODUCTION

Creativity has been considered a key factor to boost organizational effectiveness in post-industrial environments. As such environments pose new challenges; organizations are required to find novel ways to deal with more complexity and increased turbulence. In order to respond quickly to the constant and unexpected changes, organizations rely increasingly on teamwork. Group Support Systems (GSS) have been used to improve the generation of creative solutions by teams (Santanen, E.L., R.O. Briggs, G.J. de Vreede, 2000), consequently improving the effectiveness of the decision-making processes.

Creativity researchers have mainly focused on the qualities of the creative person or group, the creative product, or the contextual variables that affect creativity. Prior research has focused largely on creativity in the following dimensions: a) the idea generation phase of problem solving (Hender, J.M., T.L. Rodgers, D.L. Dean, & J.F. Nunamaker Jr., 2001; Massetti, B. 1996; Sosik, J.J., B.J. Avolio, B.J. & S.S. Kahai, S,S., 1998), b) the impact of technical aspects (Fjermestad, J., & S.R. Hiltz, 1999), and c) the cognitive, social and procedural structures behind creativity (Bostrom, R.P. & M. Nagasundaram, 1998). Very few studies have explored the process behind creativity. This research will look at creativity in GSS environments, from a process standpoint, and focusing on the output of the whole problem solving process. Understanding which types of processes yield increased levels of creativity is the main goal.

Group processes can be more or less restrictive, depending on the extent to which there is a pre-defined sequence of tasks they should go through when solving problems. Some researchers claim that "laissez-faire" group processes result in higher levels of group creativity, are more favorable to innovation, or provide freedom to try new ways of performing tasks. This research explores two group Process Structures in terms of their level of restrictiveness, and their impact on group creativity in electronic-mediated meetings. The two structures are: Standardization of Processes (SP) and Standardization of Outputs (SO). Additionally the research explores task complexity or uncertainty as an intervening variable affecting the relationship between structure and creativity.

PROCESS STRUCTURE, TASK COMPLEXITY AND CREATIVITY

Innovation and creativity mean to break away from highly formalized behaviors (Mintzberg, H., 1979). The literature on group innovation and creativity mentions five sets of antecedents to creative processes, namely (i) leadership, (ii) group cohesiveness, (iii) group longevity, (iv) group composition, and (v) group structure (King, N., & N. Anderson, 1990). High levels of innovation are facilitated by leadership styles that promote democratic collaboration. While low cohesiveness is necessary in the earlier stages of innovative processes, higher levels are required in subsequent phases (Nyström, H., 1979). In terms of group composition, minority influence theories argue that minority sources lead to more divergent thinking, which in turn establishes the ground for creative solutions (Nemeth, C.J., 1986). Finally, the level of restrictiveness of a group's structure and the group's degree of innovativeness are related (Meadows, I.S., 1980). This study focuses on the last set antecedent, that is, group structure and its impact on creativity.

A few authors assert that some level of structure is conducive to creative solutions, and that too much structure or the wrong structure may render the group process non-creative. "Laissez-faire" group structures are said to result in higher levels of group creativity (Glover, J.A., 1979). Low levels of restrictiveness are claimed to be favorable to innovation (Holbek, J., 1988). Finally, the provision of freedom to try new ways of performing tasks is claimed to be a necessary condition for creativity (Isaken, S.G., 1988). Nonetheless, the level of group structure did not have an impact on group's creativity in one case (Ocker, R., S.R. Hiltz, M. Turoff, & J. Fjermestad, 1995).

Groups' process structures are dependent on coordination needs. Coordination modes that yield effective performance are a function of groups' structural characteristics and the complexity of the group's task (Dailey, R.C., 1980). The nature of the group interactions becomes mostly determined by the level of task complexity (Hackman, J.R., 1968). Group size and cohesiveness mediate this causal relationship (Dailey, R.C., 1980).

Tasks are usually classified in terms of both level of goal agreement and beliefs about causation (Thompson, J.D., & A. Tuden, 1959). Complexity is defined as a function of the amount of relevant information that has to be processed to attain a solution. Decision-makers deal with both a broad span of goals, and a considerable number of pieces of information associated with each course of action. In one case, group members deal with information that enables the definition of the desired outcomes (i.e., goal agreement). In the other case, they deal with information that allows them to elucidate the associative links between actions and consequences. The lack of knowledge concerning these links has been referred to as task uncertainty.

When group members face an undetermined number of pieces of information associated with each course of action, standardization helps groups to reduce the task-related uncertainty (Mintzberg, 1979). In certain tasks, the options and their consequences can be fully determined in advance (Mintzberg, 1979). The contents of the task can be specified and programmed, by means of rules and procedures to secure acceptable outcomes (i.e., Standardization of Processes, SP) (Mintzberg, 1979). On the contrary, in uncertain tasks, options and consequences are not fully known, and the group is forced to turn to standardization of outputs (SO). While maintaining control, SO allows task-doers sufficient autonomy to manage their sub-tasks (Mintzberg, 1979).

If conflicting preferences about outcomes and internal conflicts over goals and values exist, a social process is needed to handle the level of goal disagreement. Group members engage in less structured interactions to generate a shared interpretation of the task at hand. This social process corresponds to a process of informal communication, that is, mutual adjustment (Mintzberg, 1979).

RESEARCH FRAMEWORK

Based on the discussion in the previous section the research framework presents two basic hypotheses. The first relate to the structure of the process and the second relate to task complexity or uncertainty.

SO provides structures that are less restrictive than those available under SP. Restrictive processes may exert pressure on the group to spend less time in the generation of alternative courses of action (11). On the contrary, less restrictive structures allow members to share ideas directly and increase the occurrence of novel associations, and hence of creative solutions (Van de Ven, A.H., & A.L. Delbecq, 1971). SO is hypothesized to (i) favor more divergent thinking, (ii) reduce conformity pressures, (iii) make possible for groups to spend more time in the generation phase, and (iv) increase the level of group creativity.

Hypothesis 1: Group processes based on SO will render the group more creative than those based on SP.

In highly uncertain tasks, group members spend a great deal of time gathering and sharing relevant information. As they engage in more information-exchanging activities, they consider more relevant pieces, and hence a broader set of alternative courses of action. When the pieces of new information are abundant, there is more need to share them directly. Direct sharing is related to the development of novel associations and, ultimately, to creativity (Van de Ven, A.H., & A.L. Delbecq, 1971).

Hypothesis 2:	Groups working on high-uncertainty tasks will generate more creative solutions than those groups working on low-uncertainty tasks.

RESEARCH DESIGN

The study used a 2x2 simple factorial design, fully counterbalanced for both variables: Uncertainty (i.e, the amount of informational exchange) and Standardization (i.e., amount of restrictiveness).

Two versions (i.e., low and high uncertainty) were developed for the selected task, a marketing case from HBP. Two experts rated the cases in terms of equivocality, uncertainty, and level of goal agreement (Cronbach's Alpha for the combined set of scores was 0.702). According to them, the levels of both equivocality and goal disagreement were low.

Two process structures were used, namely SP and SO. Under SP, groups were asked to follow a sequenced approach in their dealing with the task. The sequence imposed a tight process, with little room for improvisation. Under SO, groups were given more flexibility. They were asked to include three parts in the formal final report: issues, assumptions, and recommendations.

The GSS used provided an asynchronous electronic environment in which groups solved the case. Thirty-two groups (two four-person groups, and thirty three-person groups) that participated in the experiment were randomly assigned to one of the four conditions. There were not statistical differences between conditions for all the contextual factors. Facilitation of the group process was precluded by the design of the experiment.

Ninety eight undergraduate students, mostly in their junior and senior years, participated in the study. Extra credit was given for participation. The average age was 26 years, with an average of 4.4 years of experience. They reported to have moderate levels of experience in business environments, and low levels of experience working with groups.

Creativity was rated by a panel of experts (Cronbach's Alpha = 0.743). "A product or response is creative to the extent that appropriate observers independently agree it is creative…A product or response will be judged as creative if (a) it is both a novel and appropriate, useful, correct or valuable response to the task at hand, and (b) the task is heuristic rather than algorithmic." (Amabile, 1983: 31).

The hypotheses were tested using GLM ANOVA. According to values for the Shapiro-Wilk statistic, the observations were taken from populations normally distributed. Furthermore, the values for the Hartley statistic led to the acceptance of the null hypothesis that the variances for each set are equal

RESULTS

Tables 1 and 2 present the means and standard deviations by condition, and the ANOVA results for the set of hypotheses. According to these results, type of structure and level of uncertainty have an impact on creativity.

Based on the overall results, when the level of task uncertainty is higher, groups tend to be more creative (p=0.09). Interestingly, the results for the Type of Standardization are opposite to those hypothesized. When the coordination mechanism is more restrictive, that is, it explicitly defines the steps of the decision process, groups tend to be more creative (p=0.04)

Table 1: Creativity: Means, (Standard deviations)

Condition	Low Uncertainty	High Uncertainty	Totals
SP	61.67 (11.88)	77.90 (14.15)	69.24 (15.06)
SO	42.33 (15.30)	59.11 (23.71)	51.22 (21.40)
Totals	52.00 (16.58)	67.33 (21.74)	59.67 (20.55)

Table 2: ANOVA results

Hypothesis	F-Value	DF	p-value
Process Structure	4.67	1,28	0.04
Uncertainty	3.06	1,28	0.09

DISCUSSION

Overall, the study provided empirical evidence to support the claim that both the type of standardization of the group process and the level of task uncertainty have an impact on group creativity.

Although the type of process standardization affects the creativity of a group, the results were opposite to those hypothesized. When the group process is less restrictive, groups are less creative (p=0.04). This result may be due to the so-called "multi-headed animal syndrome" (Smith, J., & M.T. Vanececk, 1989). According to it, the lack of an orderly process may render the group process ineffective. Nobody seems to take the initiative and nothing seems to happen. Although asynchronous communication allows more time for reflective thinking, there is a tendency to procrastinate and become side-tracked. For some group members, frustration from the lack of a sense that something is happening contributes to a perceived lack of progress toward a goal. Although there are several techniques available to counter this asynchronous ineffectiveness and regulate GSS groups' behavior (e.g., facilitation), the empirical design precluded using them.

A "fading motivation" may have had a role in this result. The perceived process gains that were present in the earlier stages of the groups' decision processes wore out as groups moved to the later stages, due to the lack of participation. The initial motivation probably faded away and the final solution failed to include the richer set options originally considered. Participation, which was moderate to high in the early stages, declined for SO groups as the experiment progressed.

The nature of the groups used (i.e., ad-hoc) could also have impacted this result. Teamwork takes place in a variety of settings, which condition the life of a team and the nature of its processes. By their nature, ad-hoc groups lack a broader context. Had it existed, contextual norms may have pushed groups to move forward, not to become side-tracked.

The low-significant result for uncertainty may be associated with the low structural discriminability of the uncertainty manipulation, although its operational discriminability seemed acceptable. Structural discriminability refers to the capacity of the manipulation to express the degree of differentiation that was required in the levels of this independent variable. Operational discriminability refers to the extent to which the actual use of the manipulation succeeds in distinguishing perceptions of the variable levels (Kane, J.S., & E.E. Lawler III, 1979). Although both experts and subjects perceived different levels of uncertainty (i.e., good operational discriminability), the perceptions did not correspond to the uncertainty levels intended (i.e., poor structural discriminability).

SUMMARY

In summary, when groups work under orderly decision processes, they tend to have more dynamic conversations, that is, they tend to make shorter contributions and to have more conversation rounds. The presence of such dynamism seems to entail more creative outcomes. Moreover, in tasks with higher levels of uncertainty, as group members collect and share information, their participation increases and so does the level of creativity of the group solution. The most important conclusion of this research is that If GSS groups are to be more creative, their processes need some level of structure and restrictiveness. The lack of appropriate levels of structure seems to render the group ineffective. Furthermore, when the task is more uncertain, group processes are more dynamic and groups produce more creative solutions. However, the question of what level of process restrictiveness yield the highest level of creative outcome needs yet to be answered.

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EXPERIMENTS ON DESIGN MODELS SUPPLIED BY THEIR MANUFACTURER: AN EXAMPLE OF MANAGEMENT SCIENCE IN PRACTICE

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ABSTRACT

In-line poppet valves are used in fuel supply lines as on/off and metering valves. In certain instances, the fluid mechanic characteristics and dynamic behavior of such valves become extremely important. Such instances include the use of these valves in rocket engines' fuel lines, where it is critical that precise amounts of liquid oxygen and liquid hydrogen are introduced into the engine. To study the flow characteristics of these valves, various experiments were performed, and a summary of these tests and results are outlined in this paper.

INTRODUCTION

The experiments stated below are presented in the following sections throughout the paper.

(1) Determination of fluid flow pattern
(2) Tests on poppet valves
  A: Measurements of pressure drop across the base model design valve
  B: Measurements of force on the poppet cone of the base design valve
  C: Tests on modified design valves

GENERAL FLUID FLOW PATTERN

In many fluid flow problems, a physical insight of an overall flow behavior is essential to the analysis of flow field. Flow visualization techniques are used to obtain a qualitative understanding and knowledge about a desired flow field. This allows for observation of the behavior of the flow at different regions of interest in a flow field. Once the overall flow pattern is known, theoretical or experimental means are used to obtain more detailed information about the flow field.

The valve-housing cylinder and valve housing contours are made from clear plexiglass to allow visual observation of the flow field in the valve test section. There are three relatively large separation regions and two smaller separation regions. Flow separation causes significant losses in the kinetic energy of the moving fluid stream that translates into larger pressure loss in the flow field. To reduce the pressure losses associated with flow separations, some modifications were made to the valve poppet cone and upstream housing. The rationale for new designs and the effects of various modifications on the flow field over the poppet valve are presented. In the next section, tests designed to evaluate the performance characteristics of the poppet valve under investigation are presented.

TESTS ON POPPET VALVES

Various experiments were conducted to study the fluid flow properties over the poppet valve. To present the results obtained from these experiments, it is necessary to establish a systematic procedure of referring to different tests performed on different poppet valve configurations. Therefore, prior to presentation of the experimental results, it is appropriate to discuss the poppet valve assembly configuration along with the method of referencing the assembly to different valve configurations.

MEASUREMENTS OF PRESSURE DROP ACROSS THE VALVE (BASE MODEL DESIGN)

When a fluid flows through a valve, it passes through a number of constrictions. Since certain irreversibilities associated with each expansion or contraction exist, the total useful energy of the moving fluid is reduced. This reduction of useful energy translates into loss of pressure across the valve. The pressure losses are minimal when the valve is in the fully open position. However, these losses become significantly higher when the valve is operating in a partially open or nearly closed position, and at the same time the internal flow fields become more complex. These conditions add considerably to the complexity of the theoretical modeling of such flow cases. Therefore, experiments are necessary to predict the performance characteristics and pressure loss coefficient of the flow over a valve.

The pressure loss coefficient, ζ , is related to the pressure drop across the valve, ΔP, average velocity of the fluid in the approach piping to the valve, $\overline{V}$, and the density of the flowing medium, *p*, by:

a) $$\zeta = \frac{\Delta P}{\frac{1}{2}\rho \overline{V}^2}$$

To calculate ζ, the pressure drop across the valve and the average upstream velocity of the approaching flow are required. These quantities were measured experimentally for different poppet valve configurations. The tests on poppet cone #1, H1 (the base model poppet valve design configuration) are considered first. This model was tested at the fully open position and at partially open/closed positions.

MEASUREMENTS OF FORCE ON THE POPPET CONE AT VARIOUS OPENING POSITIONS

In the above discussion, it was shown that as the poppet cone was moved downstream from its fully open position, the pressure drop across the valve section increased significantly. Since larger pressure differences across the valve produce larger forces on the poppet cone of the valve, it was necessary to study the forces exerted on the valve during opening/closing positions. Therefore, the poppet cone was moved downstream from its fully open position to a nearly closed position at intervals of 5 mm. For each position of the poppet cone, the drag force, the dynamic pressure upstream, and the temperature of the water were measured at different flow rates. The drag force was then plotted vs. average velocity for the different valve
opening/closing positions. All the curves have parabolic shapes indicating that if the average velocity is increased by a factor of two, then the drag force is increased by a factor of four.

TESTS ON MODIFIED DESIGN VALVES

Minimizing pressure losses improves the performance of the valve. To achieve this goal, in addition to the components of the base model design valve, four other upstream housing contours and two other poppet valve cones were designed. The downstream housing contour design was not changed for sealing purposes. The static pressure loss across the test section and the dynamic pressure upstream of the test section were measured for different poppet valve cones with combinations of various upstream housing contours at different upstream velocities. The average velocity was calculated by using an equation that is valid for fully developed turbulent pipe flow (Fox & McDonald, 1985).

CONCLUSION

Table 1, on the following page, provides a summary matrix of the test results.

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TABLE 1: SUMMARY MATRIX OF TEST RESULTS

	Poppet Cone and Position	Upstream Valve Housing Contour	$\zeta = \frac{\Delta P}{\frac{1}{2}\rho \bar{V}^2}$ $C_D = \frac{F_D}{\frac{1}{2}\rho \bar{V}^2 A_{popp.}}$	Velocity (m/s)	Reynolds No.
A	Poppet Cone #1 Fully Open	Contour #1	ζ =0.82 C_D=0.89	$\bar{V}$ = 2.98	Re=$2.63 \cdot 10^5$
B	Poppet Cone #1 -5 mm	Contour #1	ζ =0.93 C_D=1.34	$\bar{V}$ = 2.66	Re=$2.35 \cdot 10^5$
C	Poppet Cone #1 -10 mm	Contour #1	ζ =1.26 C_D=2.42	$\bar{V}$ = 2.66	Re=$2.35 \cdot 10^5$
D	Poppet Cone #1 -15 mm	Contour #1	ζ =3.08 C_D=4.09	$\bar{V}$ = 2.65	Re=$2.34 \cdot 10^5$
E	Poppet Cone #1 -20 mm	Contour #1	ζ =7.68 C_D=10.75	$\bar{V}$ = 1.49	Re=$1.32 \cdot 10^5$
F	Poppet Cone #1 -25 mm	Contour #1	ζ =29.39 C_D=26.42	$\bar{V}$ = 1.14	Re=$1.00 \cdot 10^5$
G	Poppet Cone #1 -30 mm	Contour #1	ζ =60.53 C_D=55.04	$\bar{V}$ = 0.78	Re=$6.89 \cdot 10^4$
H	Poppet Cone #1 Fully Open	Contour #1 with Flow Deflectors A, B, C	ζ =1.36	$\bar{V}$ = 2.94	Re=$2.56 \cdot 10^5$
I	Poppet Cone #1 Fully Open	Contour #1 with Flow Deflectors A & C	ζ =1.11	$\bar{V}$ = 2.80	Re=$2.44 \cdot 10^5$
J	Poppet Cone #1 Fully Open	Contour #1 with Flow Deflectors B & C	ζ =1.14	$\bar{V}$ = 2.83	Re=$2.46 \cdot 10^5$
K	Poppet Cone #1 Fully Open	Contour #2	ζ =0.69	$\bar{V}$ = 2.66	Re=$2.43 \cdot 10^5$
L	Poppet Cone #1 Fully Open	Contour #3	ζ =0.77	$\bar{V}$ = 2.49	Re=$2.28 \cdot 10^5$
M	Poppet Cone #1 Fully Open	Contour #4	ζ =0.81	$\bar{V}$ = 2.86	Re=$2.53 \cdot 10^5$
N	Poppet Cone #3 Fully Open	Contour #1	ζ =0.71 C_D=0.37	$\bar{V}$ = 3.01	Re=$2.45 \cdot 10^5$
O	Poppet Cone #3 -10 mm	Contour #1	ζ =0.99 C_D=0.98	$\bar{V}$ = 2.81	Re=$2.28 \cdot 10^5$
P	Poppet Cone #3 -20 mm	Contour #1	ζ =5.58 C_D=3.36	$\bar{V}$ = 2.30	Re=$1.87 \cdot 10^5$
Q	Poppet Cone #3 -30 mm	Contour #1	ζ =92.68 C_D=58.15	$\bar{V}$ = 0.63	Re=$5.12 \cdot 10^4$
R	Poppet Cone #3 Fully Open	Contour #3	ζ =0.80	$\bar{V}$ = 3.27	Re=$2.54 \cdot 10^5$
S	Poppet Cone #3 +8.4 mm	Contour #3	ζ =0.56	$\bar{V}$ = 3.20	Re=$2.66 \cdot 10^5$
T	Poppet Cone #3 +16.5 mm	Contour #3	ζ =0.58	$\bar{V}$ = 3.20	Re=$2.66 \cdot 10^5$
U	Poppet Cone #3 Fully Open	Contour #4	ζ =0.83	$\bar{V}$ = 3.18	Re=$2.24 \cdot 10^5$
V	Poppet Cone #3 +8.4 mm	Contour #4	ζ =0.79	$\bar{V}$ = 3.16	Re=$2.29 \cdot 10^5$
W	Poppet Cone #3 +16.5 mm	Contour #4	ζ =0.80	$\bar{V}$ = 3.14	Re=$2.28 \cdot 10^5$
X	Poppet Cone #3 Fully Open	Contour #5	ζ =0.75	$\bar{V}$ = 3.26	Re=$2.60 \cdot 10^5$
Y	Poppet Cone #3 +5 mm	Contour #5	ζ =0.49	$\bar{V}$ = 3.26	Re=$2.53 \cdot 10^5$
Z	Poppet Cone #3 +8.4 mm	Contour #5	ζ =0.47	$\bar{V}$ = 3.25	Re=$2.36 \cdot 10^5$
AA	Poppet Cone #3 +10.5 mm	Contour #5	ζ =0.47	$\bar{V}$ = 3.26	Re=$2.53 \cdot 10^5$
AB	Poppet Cone #3 +12 mm	Contour #5	ζ =0.48	$\bar{V}$ = 3.24	Re=$2.51 \cdot 10^5$
AC	Poppet Cone #3 +14.2 mm	Contour #5	ζ =0.48	$\bar{V}$ = 3.25	Re=$2.36 \cdot 10^5$
AD	Poppet Cone #3 +10.5 mm	Contour #5 moved +10 mm	ζ =0.42	$\bar{V}$ = 3.24	Re=$2.35 \cdot 10^5$
AE	Poppet Cone #3 +10.5 mm	Contour #5 moved +10 mm**	ζ =0.37	$\bar{V}$ = 3.30	Re=$2.65 \cdot 10^5$

** A single leg support is used to hold the valve in the test section

CASE USE: MIXED SIGNALS FROM THE MARKETPLACE

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ABSTRACT

Continuing system development problems are causing organizations to seek methods and tools that will improve the efficiency and effectiveness of system development projects. One set of tools that have long promised to alleviate many system development problems has been computer-aided system engineering (CASE) tools. While these tools have been around for nearly two decades, previous research had indicated that organizations were being slow to jump on the CASE tools bandwagon. This study reports on a survey of IS professionals in the United States to compare CASE tool adopters to non-adopters today with CASE tool adopters and non-adopters of a decade ago. The results indicate that while the number of CASE tool adopters has remained relatively stable, the characteristics of those adopters has changed in some important aspects such as the size of the organization and the seniority of the CASE tool users.

INTRODUCTION

Information systems (IS) may be the real "field of dreams." IS professionals live at the intersection of "what-is" and "what could be." IS is an agent of change - a place where possibility meets reality. With the possible exception of the research and development function, no other unit within an organization spends so much of its time and resources working from a blank slate. This culture of "creativity" naturally yields both "hits" and "misses."

The curtain is drawing on the era of run-away IS budgets fueled primarily by market euphoria and competitive fear. As more technologically savvy functional area managers come to the planning table, the shine is dimming on the mystique of the "black box." The maturing of the IS function must include the means for effectively sorting through the promises without fatally puncturing the idealism inherent in its culture (Persse, 2001).

Is Computer-Aided Software Engineering (CASE) a "hit" or a "miss?" Is it just another in a long string of exaggerated broken promises or is it an evolving tool swimming upstream against unrealistic expectations? The verdict is not clear but the evidence suggests a split house, with long-term CASE users fairly entrenched despite a dim future for the prospect of new adoptions (Finlay & Mitchell, 1994). A look at CASE use over time will shed insight on this controversial tool and, hopefully, help IS professionals develop skills in making the distinction between solutions and promises.

The underlying concept of CASE is too appealing to let die. The idea of systems that help produce systems is both sensational and sensible. Most companies struggle to bring information systems development projects to fruition on schedule and within budget while still providing all the requested functionality (Jalote, 2000).

Unfortunately, while CASE rolled out to great accolades, it has faced criticism early and often. Headlines such as "CASE Bandwagon Loses a Wheel" (Lauchlan, 1992) and "CASE Fights All Talk and No Action Image" (Margolis, 1988) announced its demise with dramatic fanfare almost before it got off the ground. For many, CASE has been just another unfulfilled promise (Glass, 1999).

In spite of being nearly stillborn and struggling both technically and financially through its adolescence, CASE is not dead. In fact, some reports suggest that new emphases like ERP and Object Oriented Programming have led to a resurgence of interest in CASE over the last few years (Hayes, 1997; Post & Kagan, 2001).

CASE promises to help organizations develop and maintain system solutions much faster and at far less cost than more traditional analysis and design methodologies (Nelson & Rottman, 1996). CASE tools assist IS professionals in the development of information systems by facilitating methodology activities and enforcing methodology rules and requirements. The potential benefits of CASE tool usage are apparent and have been documented (Post, Sambamurthy, & Zmud, 2000). However, adoption of CASE tools was originally slow and the use of CASE tools by IS professionals continues to be limited (Hughes & Clark, 1990; Hapgood, 2000). Slow adoption rates in the face of evidence of successful application of the technology suggest that CASE may need a closer look.

METHODOLOGY

A survey was mailed to 965 private sector IS professionals randomly selected from among the Association of Information Technology Professionals (AITP) membership roster. To protect the privacy of AITP members and honor the contractual commitments of the list access agreement, the researchers were not given the names or addresses of the subjects and no follow-up mailings or contact was allowed. The data collection process produced 83 usable surveys. The 8.6% response rate is considered good for a single cycle, mail project without follow-up reminders.

Hughes and Clark used the same survey instrument in 1990 to conduct a similar study. The earlier research by Hughes and Clark was also conducted with the assistance of the AITP (then, Data Processing Management Association). The nature of the data presented in Hughes and Clark (1990) limit the types of statistical comparisons that can be made across studies, however, the similarities in the instruments do allow for some comparisons to be made.

RESULTS

Where appropriate, the data were analyzed using a 2 test for homogeneity of proportions. Since the expected frequency for all cells in the contingency tables are at least 5, the 2 test for homogeneity of proportions is considered to be robust (Berenson & Levine, 1999). However, this statistical procedure is only appropriate when there are exactly two rows in the contingency tables. While it is not appropriate to draw statistical conclusions from some of the analysis of the results of the two surveys, the similarity of the instruments and the studies makes for interesting comparisons.

CASE Use by Organizations Remains Steady

Twelve years and incredible technological changes later, the number of responding organizations using CASE is virtually unchanged. In 1990, Hughes and Clark reported that 33% of the responding organizations were CASE users and, in 2002, the number of responding organizations using CASE was 36%.

Table 1: CASE Use by Organizations

	1990	2002	χ^2	p
% of Organizations Using CASE	33%	36%	0.239	NS

Given the often-heard arguments that CASE is a technology whose time has come (if at all) and gone, the 36% rate of use in 2002 is noteworthy. Perhaps, it suggests that rumors of its demise are greatly (or, at least somewhat) exaggerated.

CASE USE BY INDIVIDUALS - A MIXED BAG

In spite of the reported steady use of CASE by organizations, the survey results reflect a drop-off among responding individuals who use CASE from 31% in 1990 to 18% in 2002.

Table 2: CASE Use by Individuals

	1990	2002	χ^2	p
% of Individuals Using CASE	31%	18%	5.136	<.05

While no firm conclusion can be drawn from this drop-off, it is plausible to suggest that since 36% of the respondents are in organizations that use CASE, the difference in the rates of individual use of CASE is a function of the coincidence of who within the organization received the survey instrument. Since both the 1990 and the 2002 surveys were mailed to senior IS professionals, it is also reasonable to suggest that the use of CASE has become more specialized over the past twelve years. This specialization could tend to localize the responsibility for CASE use among a smaller subset of IS professionals.

STABLE LONG TERM COMMITMENT AND SOFT SHORT TERM ADOPTION

Responding organizations that use CASE tools tend to be long time users. Only 20% of the organizations using CASE tools indicated that they have been using the tools for less than four years. Eighty percent of the organizations using CASE have been using it for four or more years.

In the 1990 study, the length of service differed little within individual CASE users. The current study found that the gap in length of service has shifted. Among CASE users, most (65.5%) have been with the firm for four years or more, while only 34.5% have been with the firm less than four years, whereas in 1990 there was little difference (47.5% vs. 52.5%).

Table 3: Length of Service and CASE Use

	Three Years or Less	Over Four Years
1990	47.5%	52.5%
2002	34.5%	65.5%

The 1990 data seemed to suggest that senior IS professionals were reluctant to embrace the new CASE technologies. Today CASE is more likely to be the domain of experienced developers. It may be that the longer length of service among individual CASE users indicates the relatively early adoption and continuous use of the technology.

It is impossible to ascertain whether the primary catalyst for the association between longer service and CASE use is product satisfaction or professional inertia borne out of large investments in early commitments or even just resistance to change. Whatever the reason, the data suggests that the shift in experience among CASE users may be dramatic.

CASE USE AND FIRM SIZE: A MAJOR SHIFT

A substantial shift also appears to have occurred in the past twelve years in regard to the size of the firms using CASE tools. In 1990, CASE tool use appeared to be more prevalent in large firms (greater than $100 million). In 1990 only 25% of the responding smaller firms (less than $100 million revenue) reported CASE use, while 62.5% of the responding larger firms reported CASE use. In 2002, the results reverse dramatically with 53.3% of the smaller firms and only 30% of the larger firm reporting CASE use.

Table 4: CASE Use and Firm Revenue			
	Small ($100 million or less)	Large (Over $100 million)	N/A (Not Reported
1990	25.0%	62.5%	12.5%
2002	53.3%	30.0%	16.7%

This shift in emphasis to smaller organizations may be the result of the growth in power of microcomputers and the reduced cost of running these systems. In 1990, many CASE tools required powerful multi-user systems operating on mid-range or mainframe computers. Today, microcomputers have the processing capability necessary to power CASE tools thus making them more accessible to a wider range of organizations.

THE IMPEDIMENTS TO ADOPTION: KNOWLEDGE AND MONEY

Non-CASE user firms were asked to indicate their reasons for not adopting the tools. The reasons for non-adoption of CASE were grouped into two categories "Knowledge" and "Financial." "Knowledge" reasons included those items that deal with issues such as being unfamiliar with CASE tools and a perceived lack of benefits of using CASE tools. "Financial" reasons included the costs of the tools exceeding the potential benefits and a lack of financial resources to invest in CASE tools.

Table 5: Reasons for Non-Use of CASE by Firm Size				
	Knowledge		Financial	
	1990	2002	1990	2002
Small	40.9%	34.5%	50.0%	62.1%
Large	26.7%	50.0%	46.6%	44.4%
N/A	26.3%	33.3%	47.4%	55.6%

In spite of over a decade of market availability, large firms are more likely to reject CASE tools for "knowledge" reasons in 2002 than in 1990. The percentage of large firm rejecting CASE tools for "financial" reasons has remained relatively constant from 1990 to 2002. This could suggest that large firms have failed to realize the anticipated benefits of CASE tools and no longer see their benefit.

Even with widespread CASE availability on less expensive platforms, smaller firms "financial" concerns with CASE adoption have increased since 1990 from 50% to 62.1%. The "knowledge" concerns of smaller firms have been modestly reduced from 40.9% in 1990 to 34.5% in 2002.

AN UNCERTAIN FUTURE FOR CASE

The number of firms responding with "considering" is down dramatically. A "considering" response indicates that the firm is seriously looking at adopting a CASE tool. If this reduction is an indicator of intent to purchase, the future for CASE technology is, at best uncertain.

In 1990, over 60% of large firms used CASE and over 25% of the non-user firms were actively considering it. Therefore, in 1990 it was an unusual large firm that was not actively involved in either using or considering using CASE. Over 85% of all large firms responding to the 1990 survey were either using CASE or considering using CASE. In the 2002 survey only 35.6% of responding large firms are either using or considering using CASE. The percentage of larger firms considering the use of CASE dropped dramatically from 26.7% in 1990 to 5.6% in 2002. A large drop was also present in smaller firms, from 9.1% in 1990 to 3.4% in 2002.

Table 6: Considering CASE Use by Firm Size

Considering CASE Adoption in	1990	2002
Small	9.1%	3.4%
Large	26.7%	5.6%
N/A	26.3%	11.1%

If the percentage of responding firms presently considering using CASE is an accurate indicator, then the market has peaked and the future for CASE is uncertain.

CONCLUSION

The current study looks at CASE tool users and non-users to try and shed light on the lack of CASE tool adoption among IS professionals. Despite the potential benefits of using CASE tools to help IS organizations complete development projects on schedule, within budget, and with the necessary functions and features, CASE tool adoption, while somewhat stable, is still limited. The data also suggest that the trend is toward less rather than more adoption.

Is the promise of CASE largely unfulfilled? In many instances, the answer is yes. However, CASE is not dead, in fact, in a surprisingly large number of organizations of all sizes it appears to have taken root. The stability among existing CASE users and the reluctance among non-users adds another chapter to the paradox of information technology adoption. It appears that those who use CASE like it and those who do not use CASE are not likely to try it.

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PRODUCTION & OPERATIONS QUALITY CONCEPTS: DEFICIENT DIFFUSION INTO THE SERVICE SECTOR

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ABSTRACT

Over the past 25 years, America has migrated from an industrial economy toward information, technology and service. The shift is well documented by various statistics regarding the declining balance of manufacturing exports-to-imports, declining manufacturing employment and declining direct labor content within goods, as well as through the transformation of the Dow Jones Industrial Average components.

The production/operations management discipline has been slow to respond. Since 1992, only the smallest percentage of academic articles in the leading production/operations management journals have been devoted to service operations. Textbook content reveals only the weakest trend to alter the classic manufacturing paradigm toward services.

Accordingly, this paper hypothesizes that basic quality concepts embedded within the production/operations management body of knowledge have been slow to transfer into the service sector. The survey instrument, involving 126 service corporations across 32 industries, enjoyed a 91% response rate. The results find that the overall degree of knowledge in the service sector is very low. Many of the resulting means placed within the lowest quartile of the Likert scale. The authors hope that this paper and evidence will effectively serve as a call for production & operations management academics to more aggressively shift their discipline perspective toward services.

THE RISE OF SERVICE AND THE DISCIPLINE PERSPECTIVE

Over the past twenty-five years, America has migrated from an economy based upon industrial and manufacturing activity toward an economy, to great extent, based upon information, technology and service—in agreement with the prophetic 1980 perspective of futurist Alvin Toffler (1980). There is little doubt that the service sector has now all but replaced the dominance of the manufacturing sector within the American economy. By 1990, service accounted for 72% of U.S. Gross National Product (U.S. Bureau of Economic Analysis, 1991) and accounted for 70% of American employment (Schmenner, 1995). Employment in the manufacturing sector began a rapid decline during the late 1990s, with 3 million jobs lost between 2000 and 2003, that being one-sixth of the total manufacturing sector (Anonymous, 2003a, 2003b) , while the number of Americans employed in service continues to increase (Stevenson, 1996). The American economic shift away from manufacturing toward service is also well documented with various other economic statistics regarding the declining balance of manufacturing exports-to-imports, declining manufacturing employment and declining direct labor content within goods.

Perhaps even more persuasive evidence of the American economic shift from manufacturing toward service in the last twenty-five years is found within the composition of the thirty component corporations of the Dow Jones "Industrial" Average (DJIA); during that time, the component basis of the DJIA has steadily moved toward service. Table 1 displays a number of significant changes evidencing the trend (Dow Jones & Company, 2004; Shell, 2004).

Table 1
DJIA Component Replacements Toward Service Content

New Component	Replaced Component	Year
American Express	Manville Corporation	1982
McDonalds	General Foods	1985
Disney	U.S. Steel	1991
J. P. Morgan Chase	American Can	1991
Citigroup	Westinghouse	1997
Wal-Mart	Woolworth	1997
Microsoft	Chevron	1999
SBC Communications	Union Carbide	1999
Home Depot	Sears, Roebuck	1999
American International	International Paper	2004
Verizon	AT&T	2004
Pfizer	Eastman Kodak	2004

According to a recent USA Today article (Shell, 2004), the 1999 changes represented the point at which "the stodgy index that once tracked the smokestack economy went ‘new economy.'" The article also states that International Paper "was expelled because basic materials matter less in today's information-based economy." In addition, other long-standing DJIA component corporations such as IBM and Honeywell have clearly shifted a significant percentage of their core business into the service sector. With similar perspective, Fortune magazine stopped distinguishing between service and manufacturing within its Fortune 500 list during the 1990s.

The rise of service is also evidenced throughout much of the industrialized world as well, representing nearly 70% of the civilian labor force in Canada, Australia, France and the Netherlands and nearly 50% in Germany, Japan and Italy (U.S. Bureau of Economic Analysis, 2002).

The academic perspective regarding production & operations management, however, remains stubbornly focused upon its manufacturing paradigm "roots" rather than shifting toward services. The authors reviewed 217 abstracts from Journal of Operations Management, generally recognized as the discipline's leading journal (Barman, Hanna, & LaForge, 2001; Barman, Tersine, & Buckley, 1991; Soteriou, Hadjinicola, & Patsia, 1999; Vokurka, 1996). The review, which included the articles published from 1993 through 2001, found no more than seven articles (3.2% of the total articles) squarely focused upon the topic of service operations (Heineke, 1995; Karmarkar & Pitbladdo, 1995; Kellogg & Nie, 1995; Miller, Craighead, & Karwan, 2000; Narasimhan & Jayaram, 1998; Soteriou & Chase, 1998; Stank, Goldsby, & Vickery, 1999) and no more than 18 articles with some significant degree of service operations content. In contrast, 68 articles (31.3% of the total articles) were found to have "classic" topics such as planning, scheduling, forecasting and production control intended for the manufacturing environment.

Even the most cursory longitudinal examination of production & operations textbooks reveals only the weakest trend to alter the classic manufacturing perspective or to add service content. For example, the index of the 1996 edition of the best-selling production & operations management textbook (Stevenson, 1996) identifies only 17 of its 897 pages (1.9%) as pertaining to services; the index of the 2005 edition (Stevenson, 2005) identifies only 35 of its 871 pages (4.0%) as pertaining to services. In 2003, a major production/operations textbook (Heizer & Render, 2003) did adopt a predominant service theme in its seventh edition, threading its examples through a case based upon the Hard Rock Café. For the most part, however, the production & operations management discipline persists in perceiving service operations as distinct from the production & operations discipline, as evidenced by brand-new textbooks dedicated solely to service operations such as Davis & Heineke (2003) as well as continuing editions of dedicated service operations textbooks such as Fitzsimmons & Fitzsimmons (2004).

There is even earlier evidence of the discipline's resistance to service issues. During the 1980s and early 1990s, much (though certainly not all) of the significant service operations research was actually conducted within the discipline of marketing, by researchers such as Martin Bell (1986), Mary Jo Bitner (1992), John Bowen (1990) and Christopher Lovelock (1980; 1983; 1984; Maister & Lovelock, 1982). Many of the articles authored by these researchers are still considered "service classics" and continue to strongly influence, and comprise no small portion of, the production/operations management body of knowledge with respect to services. The term "service factory" provides one example. The term, which refers to how service operations such as McDonalds are similar in nature to a traditional manufacturing operation, was popularized within the production & operations discipline by a Harvard Business Review article titled "The Service Factory," written by two productions & operations management academics possessing a special interest in services (Chase & Garvin, 1989). However, the term "service factory" actually appeared six years earlier in the marketing literature within an article authored by marketing professor Christopher Lovelock (1983). Another example involves the "classic" list of characteristics that differentiate manufactured goods from services, a list typically found in recent production & operations management textbooks; that list is essentially derived from a Lovelock services marketing text published twenty years ago (1984).

HYPOTHESES

Based upon this delay in the conversion of the production & operations management academic perspective from that of manufacturing operations toward service operations, the authors hypothesize that:

H1:	The degree of production & operations discipline concepts diffused into the practice of service operations is relatively low.

Since we suspect that there is little "formal" diffusion of these concepts, much of any existing diffusion is expected to be "informal" in nature. Under such informal diffusion, concepts that are easier for practitioners to conceptualize—or to transfer easily by "word of mouth"—may well possess higher degrees of diffusion into the service sector. Accordingly, the authors additionally hypothesize that

H2:	Differences in diffusion exist between production & operations discipline concepts transferred into the practice of service operations.

The final hypothesis concerns industry effect. All service operations and industries differ substantially, and in similar fashion, from that of traditional manufacturing operations, hence no industry effect is anticipated:

H3:	There is no industry effect upon the degree of production & operations discipline concepts diffused into the practice of service operations.

METHOD

The participants in this study were individuals selected from 126 service corporations across 32 service industries. With minimal exception, the corporations surveyed have significant national presence and were surveyed via a local unit operating within thirty miles of a specific medium-sized mid-Atlantic state university. One individual, in most cases an individual with some degree of managerial experience, was surveyed at each corporation. Table 2 presents the 32 service industries surveyed, each noted with the number of companies surveyed within that industry.

The survey employed nine-point Likert-style scales to capture self-reported degrees of knowledge regarding 24 major quality concepts (including three service quality concepts) commonly found within the production & operations management body of knowledge. The specific concepts measured are listed within Table 3 (displayed in the first Data Analysis section).

Table 2
Service Industries Surveyed

Accounting & Tax Services (2)	Consumer, Food & Beverage (28)
Automobile Rental (4)	Furniture/Appliance Rental (3)
Automobile Repair (non-dealer) (4)	Groceries (5)
Automobile Sales, New (7)	Home Furnishings, Retail (2)
Automobile Supplies, Retail (3)	Home Improvement, Retail Sales (2)
Banking (3)	Hospitality (7)
Books, Retail Sales (2)	Insurance, Consumer (3)
Cable a/o Internet Provider (2)	Letter & Package Delivery (3)
Clothing, Retail Sales (5)	Office Supplies, Retail Sales (2)
Consumer Loans (Non-Bank) (3)	Optical Goods, Retail (2)
Department Stores (5)	Real Estate Sales (3)
Drug & Sundries, Retail (5)	Retail, Miscellaneous (2)
Duplication and Binding (2)	Stock Brokerage (4)
Electronics, Retail Sales (3)	Telecommunications, Consumer (4)
Employment, Temporary (2)	Toys, Retail (2)
Extermination, Pest (2)	Video & Game Rental (2)

While the sample is intended to be representative of the population of all units of all the 126 service corporations, it is important to note that the selection of the participants in this study was based upon convenience sampling. According to Kerlinger (1986), in convenience sampling, probably the most frequent form of sampling, selection is based upon ease of accessibility. Such sampling is not truly random and therefore may impact generalizability, however, it often leads to intellectual insights not otherwise easily afforded and is generally acceptable in exploratory work. In this case, the convenience is the geographic proximity of the business establishments. Indeed, Babbie (1995) presents a specific example regarding how geographic proximity can easily result in a non-representative sample.

However, there is much academic license to legitimately employ convenience sampling within the context of this study. Kerlinger (1986) advises convenience sampling can be used "with reasonable knowledge and care" and so long as "circumspection in analysis and interpretation of data" is used. Deming (1960) states that the reader "relies upon the expert's judgment" when encountering "judgment samples … in which an expert … makes a selection of ‘representative' or ‘typical' … business establishments." Babbie (1973) states that judgmental sampling "to be done effectively … requires … expertise ... well versed … in the area under consideration so that selection … is based on an educated guess as to its representativeness."

In this study, the authors exercise that allowed reasonable judgment and expertise to argue that there exists a reasonable degree of homogeneity and representativeness across individual units of a large service company with many units comprising its national presence. Such individual units are typically governed by centralized models, procedures, training and management practices. Hence, if one manager has not been trained or exposed to a specific quality concept by his company, there is fair reason to suspect that other managers at other units have likewise been untrained or unexposed. Accordingly, the authors believe that the sample is much more representative of the population than non-representative in nature, and so sufficient for the intent of this study, i.e., to find some exploratory support for the hypotheses that have been argued. (This argument simultaneously addresses any argument regarding the sufficiency of n.) Regardless, the authors must acknowledge that geographic proximity is a formal limitation upon any conclusions and generalizations drawn from this study.

One shortcoming of the research design was that since, in a number of industries only two or three companies existed or were proximate, less reliable measures of dispersion for those industries resulted. A second shortcoming of the design is that the survey instrument was not designed to distinguish the source of the respondent's knowledge of the concepts, i.e., whether the knowledge was internally or externally derived, formally or informally diffused into the organization. It was only after the design and distribution of the instrument that the authors recognized that they might wish to control or analyze this factor. Hence, the conclusions and generalizations are also limited by these design factors.

Of the 126 survey instruments distributed, 114 usable responses were received, which translates into a 91% overall survey response rate. The high response rate is primarily attributed to the use of face-to-face method in survey distribution and collection. While there is no general safe limit to nonresponse (Deming, 1960), such a high response rate greatly reduces the risk of any nonresponse bias. Further, of the twelve nonresponses, the surveyors reported that eight nonresponses were cited as due to company policies against the release of competitive information. Consideration of this additional information, in combination with the high response rate, leads the authors to conclude the likelihood of nonresponse bias is extremely low.

DATA ANALYSIS AND CONCLUSIONS FOR H1: DEGREE OF KNOWLEDGE

Table 3 presents the descriptive statistics for each of the 24 concepts measured. These descriptive statistics indicate the overall degree of knowledge of these concepts within the service sector is very low. None of the 24 quality concepts measured resulted in a mean greater than five, the median value within the nine-point Likert scale employed. Fully one-third of the concept means fell within the lowest quartile of the scale. The grand mean of 3.04 and grand median of 2 are even stronger evidence of the overall low degree of knowledge.

While similar descriptive statistics from a sample of the manufacturing sector would be required in order to perform a formal comparison between the two sectors, the extremely low numbers tabled greatly increase the likelihood of significant difference between the two sectors. Based on the values tabled, so very near the lowest values possible, the authors conclude that the analysis provides reasonable informal evidence to support H1, that the degree of production & operations discipline concepts diffused into the practice of service operations is relatively low.

Table 3
Descriptive Statistics for Concepts Measured

Concept Measured	Mean	SD	Min	Max	Median
Benchmarking	4.76	2.75	1	9	5
14 Points for Management	3.36	2.27	1	9	3
Hidden Factory	2.44	2.02	1	8	1
Ishikawa/Fishbone Diagrams	2.5	2.09	1	9	1
ISO 9000	2.73	2.39	1	9	1
Juran's 80:20 Rule	3.05	2.35	1	9	2
Kaizen/Continuous Improvement	3.61	2.58	1	9	3
Kanban/Pull Methods	2.75	2.14	1	9	1
Kano's "Delightful Quality" Model	2.48	2.19	1	9	1
Moments of Truth	3.47	2.74	1	9	3
Pareto Charts	2.31	1.94	1	9	1
PDSA Cycle	2.67	2.13	1	8	1
Poka-Yoke & Mistake-Proofing	2.41	2.12	1	9	1
Quality Circles	3.88	2.64	1	9	4
Quality Dikes	2.82	2.23	1	9	1
Root Cause Analysis	3.94	2.68	1	9	4
Service Bookends	3.05	2.34	1	9	2
Service Recovery	3.54	2.55	1	9	3
Shingo Methods	1.94	1.77	1	9	1
Six Sigma	2.23	1.8	1	7	1
Statistical Process Control Charts	3.35	2.6	1	8	3
Taguchi Methods	1.85	1.55	1	9	1
The Four Costs of Quality	3.68	2.51	1	7	3
Zero Defects	4.14	2.73	1	9	5
All Concepts	3.04	2.42	1	9	2

Table 4
95% Confidence Intervals for Concepts Measured

Concept Measured	Mean	Lower Bound	Upper Bound
1) Benchmarking	4.25	4.76	5.28
2) Zero Defects	3.63	4.14	4.65
3) Root Cause Analysis	3.44	3.94	4.44
4) Quality Circles	3.39	3.88	4.37
5) The Four Costs of Quality	3.21	3.68	4.14
6) Kaizen/Continuous Improvement	3.13	3.61	4.09
7) Service Recovery	3.06	3.54	4.01
8) Moments of Truth	2.97	3.47	3.98
9) 14 Points for Management	2.94	3.36	3.78
10) Juran's 80:20 Rule	2.92	3.05	3.49
11) Statistical Process Control Charts	2.87	3.35	3.83
12) Service Bookends	2.62	3.05	3.49
13) Quality Dikes	2.4	2.82	3.23
14) Kanban/Pull Methods	2.35	2.75	3.14
15) ISO 9000	2.28	2.73	3.17
16) PDSA Cycle	2.27	2.67	3.06
17) Ishikawa/Fishbone Diagrams	2.11	2.5	2.89
18) Kano's "Delightful Quality" Model	2.08	2.48	2.89
19) Hidden Factory	2.06	2.44	2.81
20) Poka-Yoke & Mistake-Proofing	2.02	2.41	2.81
21) Pareto Charts	1.95	2.31	2.67
22) Six Sigma	1.89	2.23	2.56
23) Shingo Methods	1.61	1.94	2.27
24) Taguchi Methods	1.56	1.85	2.14

DATA ANALYSIS AND CONCLUSIONS FOR H2: DIFFERENCES IN CONCEPT DIFFUSION

Table 4 presents the 95% confidence intervals for the 24 concepts measured, tabled in decreasing order of the lower bound. The tabling of ranked confidence intervals, rather than a complete tabling of all possible t-tests and resulting p-values, greatly simplified the illustration of these comparisons within the confines of this paper. The confidence intervals adequately facilitate determinations regarding whether concepts significantly differ in degree of diffusion. For example, the lower bound for the benchmarking concept is greater than the higher bound of concepts 5 through 24. Hence we may conclude that the benchmarking concept has a significantly higher diffusion into the service sector than those twenty concepts. Examining the table from the bottom in similar fashion also yields significant differences. For example, the upper bound for the Taguchi Methods concept is lower than the lower bound for concepts 1 through 16. The authors note that the issues of lack of pooled variance and paired comparison place some minor limitations upon the claim of significance. The results of these comparisons are displayed in Table 5.

Table 5
Confidence Intervals Comparisons

Concept Measured	Significantly Different By Upper Bound from Concepts	Significantly Different By Lower Bound from Concepts	Not Significantly Different from Concepts
1) Benchmarking		5-24	2-4
2) Zero Defects		10, 12-24	1, 3-9, 11
3) Root Cause Analysis		13-24	1-2, 4-12
4) Quality Circles		13-24	1-3, 5-12
5) The Four Costs of Quality	1	14-24	2-4, 6-13
6) Kaizen/Continuous Improvement	1	14, 16-24	2-5, 7-13, 15
7) Service Recovery	1	16-24	2-6, 8-15
8) Moments of Truth	1	17-24	2-7, 9-16
9) 14 Points for Management	1	17-24	2-8, 10-16
10) Juran's 80:20 Rule	1-2	19-24	3-9, 11-18
11) Statistical Process Control Charts	1	19-24	2-10, 12-18
12) Service Bookends	1-2	22-24	3-11, 13-21
13) Quality Dikes	1-4	23-24	5-12, 14-22
14) Kanban/Pull Methods	1-5	23-24	6-13, 15-22
15) ISO 9000	1-5	23-24	6-14, 16-22
16) PDSA Cycle	1-7	23-24	8-15, 17-22
17) Ishikawa/Fishbone Diagrams	1-10		11-24
18) Kano's "Delightful Quality" Model	1-10		11-24
19) Hidden Factory	1-11		12-24
20) Poka-Yoke & Mistake-Proofing	1-11		12-24
21) Pareto Charts	1-11		12-24
22) Six Sigma	1-12		13-24
23) Shingo Methods	1-16		17-24
24) Taguchi Methods	1-16		17-24

Table 5 facilitates an informal categorization of the concepts into five strata: concepts 1 through 4, concepts 5 through 12, concepts 13 through 16, concepts 17 through 22 and concepts 23 and 24. The authors offer some speculation regarding of the nature of these tiers. The first-tier concepts are relatively easy to verbalize and transfer "by word of mouth." Many of the second-tier and third-tier concepts have been highly visible in press, trade magazines and popular books. The nomenclature regarding a number of the fourth-tier concepts may well be unfamiliar—results might have been different had different nomenclature been used. The fifth-tier concepts are generally more technical and complex, not easily transferred without formal study. The authors believe this argument suggests that most of the service knowledge that was measured was not transmitted through formal organizational channels.

Again, while calculation and illustration of all possible t-tests and resulting p-values would have added a slightly more formal significance, would have added the additional information that p-values offer, and would have perhaps added a somewhat more precise stratification of the concepts, the confidence interval approach tabled above is more compact and yet still yields more than adequate statistical evidence to support H2, that differences in diffusion exist between the various production & operations discipline concepts transferred into the practice of service operations.

DATA ANALYSIS AND CONCLUSIONS FOR H3: INDUSTRY EFFECT

As displayed within Table 2, only two or three useable responses per industry were collected from a number of industries. While two responses within a specific industry would technically allow for the calculation of a standard deviation, the authors believe that such deviations would not be adequately representative of the population. Accordingly, pair-wise industry comparisons were not conducted. However, an overall analysis of variance was conducted to determine whether any industry effect was present. The results of that ANOVA are displayed in Table 6.

Table 6
Analysis of Variance, Industry Effect

Source of Variation	SS	df	MS	F	p-value
Industry	74.011	30	2.467	0.913	0.599
Error	224.276	83	2.702		
Total	298.287	113			

The ANOVA finds no significant industry effect and the resulting p-value indicates any industry effect present is, indeed, quite weak. This result displayed in Table 6 allows for the reasonable conclusion that the diffusion of production & operations quality concepts into the service sector is poor regardless of the specific service industry. Accordingly, the authors conclude that support is found for H3, that there is no industry effect upon the degree of production & operations discipline concepts diffused into the practice of service operations. The conclusion serves to strengthen the notion that services, as a single entity, suffer from deficient diffusion of production and operations management knowledge.

CONCLUSION

While this study is exploratory and, to some minor degree, informal in nature, the authors believe it represents a significant contribution to discipline knowledge, in that it provides sufficient evidence that, after nearly a quarter-century of "a service economy," the production and operations discipline perspective has not sufficiently metamorphosized in a manner that would facilitate the diffusion of its body of knowledge into the service industries.

The authors have noted other calls in the production & operations management literature for researchers to redirect their research efforts when the discipline is in need of alignment. For example, in the early 1990s, a number of calls to conduct more empirical production & operations research appeared in major journals (Flynn, Sakakibara, Schroeder, Bates, & Flynn, 1990; Meredith, Raturi, Amoako-Gyampah, & Kaplan, 1989; Swamidass, 1991). The authors have found no equivalent call in the literature stating that a more significant shift in the production & operations management discipline toward service is warranted. It is hoped that this paper, as well as its exploratory evidence, illustrates the need for such a shift and that it will serve as such a call.

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