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Modeling IS Planning Benefits Using ACE

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ABSTRACT

This paper addresses the dearth of research on the determinants of IS planning benefits. Data were collected using a questionnaire survey of top IS executives from 450 companies in Singapore. Of the 103 responses (representing a response rate of 23%), 65 companies undertook IS planning. To test the hypothesis that the determinant-benefit relationships are likely to be nonlinear, the Alternating Conditional Expectations (ACE) algorithm was used. This appears to be the first use of ACE in IS planning research.

IS sophistication, communications culture, technology forecasting, top management support, and firm size were found to be nonlinearly related to IS planning benefits (e.g., improved competitiveness, operations, and resource management). For example, IS sophistication affects improved competitiveness positively, and improved resource management negatively. It seems that IS sophistication is directed more at improving competitiveness, even though this may result in less efficient resource management due to bureaucratic procedures. However, at higher levels of IS sophistication, competitiveness stagnates and may even decrease, possibly due to bureaucratic bottlenecks. Implications of our results are discussed.

Subject Areas: ACE, Benefits, Determinants, and IS Planning.

INTRODUCTION

Strategic information systems (IS) planning has consistently been rated among the top ten issues facing senior IS executives (Brancheau, Janz, & Wetherbe, 1996). Although the existing literature on IS planning deals with various aspects of IS planning, relatively little research has been done on the determinants of specific IS planning benefits. Studies dealing with benefits of specific systems exist (e.g., Sum, Yang, Ang, & Quek, 1995, with the benefits of MRP, and Cats-Baril & Jelassi, 1994, with the benefits of the French Videotex System Minitel). However, there exists few, if any, studies on the determinants of IS planning benefits. Understanding the nature of these variables would enable firms to focus their attention on appropriate areas to achieve benefits that match their IS planning objectives.

This paper identifies these variables based on an empirical study on IS planning practices in Singapore. It uses the powerful, award-winning Alternating Conditional Expectations (ACE) technique (Breiman & Friedman, 1985) to develop regression models that have a much better fit compared to those produced by standard techniques such as Ordinary Least Squares (OLS). ACE improves the model fit by suggesting transformations for both the dependent and independent variables, and the final nonlinear models often uncover new information and insights on the relationships among the variables. Such information and insights will have important implications for practitioners seeking to improve the level of benefits derived from IS planning. For researchers, such information can lead to a better understanding of IS planning relationships because conflicting results in previous studies could be due, in part, to the nonlinear nature of the relationship between independent and dependent variables.

ACE has been widely used to analyze soil-water diffusivity (De Veaux & Steele, 1989), engine exhaust emissions (Rodriguez, 1985), stress corrosion (Easton, Nelson, & Patterson, 1984), seismic studies (Brillinger & Preisler, 1984), and more recently MRP benefits (Sum et al., 1995). This paper represents the first use of ACE in IS planning research.

BACKGROUND

In this section, we examine previous research on IS planning with emphasis on determinant and benefit variables. This will enable us to identify a preliminary set of variables to be examined in this study.

Previous studies usually focus on managerial issues pertaining to IS planning (Cash, McFarlan, McKenney, & Applegate, 1992; Lederer & Mendelow, 1988a, 1988b; Raghunathan & King, 1988; Raghunathan & Raghunathan, 1994), the characteristics of firms undertaking IS planning (Conrath, Ang, & Mattey, 1992; Pavri & Ang, 1995), the IS planning process itself (Earl, 1993; Goodhue, Kirsch, Quillard, & Wybo, 1992; Ang, Shaw, & Pavri, 1995), the sustainability of competitive advantage generated by IS (Kettinger, Grover, Ghua, & Segars, 1994), IS planning problems (Lederer & Sethi, 1992), and the alignment of business and IS planning (Brown & Magill, 1994; Reich & Benbasat, 1996; Teo, 1994).

Research has also focused on the determinants of the IS planning process itself rather than of IS planning benefits. For example, Premkumar (1992) investigated IS planning characteristics among various industry groups. He found that IS planning characteristics such as IS planning resources and the role of IS vary significantly among industry groups. In contrast, there were no significant differences in terms of top management and user involvement, planning effectiveness, information input to planning, and presence of IS planning steering committee.

Other research has examined the determinants of both the quality of IS planning process and planning effectiveness (benefits). For example, Premkumar and King (1994) found that organizational characteristics (e.g., planning resources, the quality of facilitation mechanisms) were significantly associated with the quality of IS planning process and planning effectiveness (benefits). Various research on the impact of IS planning in terms of its benefits has also been carried out. In a study of the impact of IS planning on organizations, Raghunathan and King (1988) found that although both system planning and the extent of plan implementation were significantly correlated with user satisfaction, there was no significant relationship between IS planning and user satisfaction.

Teo and King (1997) examined the factors influencing the integration between business and IS planning, and found that internal factors (e.g., knowledge of IS executive about business) appear to have a stronger influence than external factors (e.g., environmental uncertainty). Furthermore, Teo and King (1996) found that greater integration between business and IS planning leads to reduced IS planning problems and greater IS contribution to organizational performance. Similarly, Lederer and Sethi (1991) also found that organizations with more sophisticated planning have significantly less hardware and implementation problems.

In summary, previous research has usually investigated the relationship between the determinant and benefit variables of IS planning indirectly. Most research focuses on the IS planning process itself rather than the benefits of IS planning. When benefits are examined, there is usually one or more intermediate variable (e.g., integration between business and IS planning) between the determinant and benefit variables. Furthermore, linearity of the relationships between determinant and benefit variables is often assumed. In this paper, we suggest that the relationships between the determinant and benefit variables are nonlinear and complex. Straightforward linear relationships, though possible, are unlikely due to the inherent complexity of organizational phenomena. It is our objective to examine the nature and complexity of these relationships.

METHOD

This section discusses the data collection procedures and the operationalizations of research variables.

Data Collection

Three research students spent two weeks telephoning some 1,400 companies picked at random from the Singapore phone book (business listing). Only those companies that had a formal IS department qualified as participants. These companies were requested to provide the name of the highest ranking IS executive to whom a questionnaire should be mailed. This sampling procedure generated a sample of 450 firms. A cover letter explaining the importance of the study and a stamped return envelope were enclosed. Of the 103 responses (representing a response rate of 23%), 65 companies (or 63% of those who responded) undertook a formal IS planning process. The response rate of 23% is comparable with other IS planning studies.

Benefit (Dependent) Variables

IS planning benefits were measured by asking respondents to indicate the extent (using a 5-point Likert scale) to which they have been achieved. The eight benefits, displayed in Table 1, were selected from previous research in IS planning. The IS planning benefits have often been measured in terms of IS contribution to organizational performance. For example, benefits such as increased market share, improved coordination and greater productivity, improved quality of products/ services, improved competitive position, and better management of resources have

Table 1: Benefit variables.

1.	Improved competitive position
2.	Improved internal coordination
3.	Improved productivity
4.	Greater ability to meet changes in the industry
5.	Improved quality in products/services
6.	Larger market share
7.	Efficient and effective management of IS resources
7.	Sound technology path and policies

Note: Variables are measured in terms of the extent to which benefits have been achieved on a 5-point Likert scale: (1 = *Low* to 5 = *High*).

often been investigated (Teo, Ang, & Pavri, 1997; Teo & King, 1996). Furthermore, IS planning can result in sound technology paths and policies, and greater ability to meet changes in the industry (Earl, 1993; Raghunathan & Raghunathan, 1994).

Determinant (Independent) Variables

The independent variables (Table 2) were also selected from previous studies in IS planning and specific systems implementation (e.g., Ahire, Golhar, & Waller, 1996; Ahituv, Neumann, & Zviran, 1989; Ang et al., 1995; Black & Porter, 1996; Conrath et al., 1992; Harris & Katz, 1991; McLean & Soden, 1977; Teo et al., 1997). These variables were categorized into two types: organizational and implementational. Organizational variables involve firm characteristics and IS sophistication whereas implementational variables involve the IS planning process itself. These variables have often been used in IS planning and systems implementation research. For example, Teo et al. (1997) reported no significant relationships between IS planning and the following variables: industry type, organizational structure, computer configuration, and systems development. However, they reported significant relationships between IS planning and the following variables: firm size and operational structure. Premkumar and King (1994) found organizational characteristics having a significant influence on the quality and effectiveness of the IS planning process. IS sophistication can also affect the level of benefits derived from IS planning (Teo & King, 1996; Premkumar & King, 1992).

In terms of implementational variables, various elements of the IS planning process have been investigated and found to be important determinants of IS planning success (see Table 2). For example, top management support (Conrath et al., 1992; Lederer & Mendelow, 1988b) and the need for clear-cut corporate plans to guide IS planning efforts (Earl, 1993; Lederer & Sethi, 1992) have often been stressed as essential ingredients in successful IS planning. Formal planning procedures are often necessary as systems become more complex, require longer development periods, involve multiple stakeholders, and cut across departments. Such formal procedures, which often include deciding on an appropriate planning horizon, also help to ensure alignment between business and IS plans so that IS can better serve business needs.

Table 2: Determinant variables.

a. Organizational variables

Firm size (interval scale)
- Company revenue
- Total number of employees
- IS expenditure
- Total number of IS employees

Industry type (categorical scale)
- Service
- Manufacturing
- Others

IS sophistication (descriptive ordinal scale)
- Alignment of IS and business plans
- Capital allocation criteria for IS projects
- Objective setting for IS personnel
- Computer operations
- Feasibility assessment of IS projects

Organizational structure (categorical scale)
- Physically centralized
- Physically decentralized

Operational structure (categorical scale)
- Functional
- Product
- Matrix
- Conglomerate

Computer configuration (categorical scale)
- Physically concentrated
- Physically dispersed
- Physically distributed

Systems development (categorical scale)
- Functionally centralized
- Functionally decentralized

b. Implementational variables

IS planning process
(Extent of importance on Likert scale:
1 = *Low* to 7 = *High*)

1. Getting top management support for the planning efforts
2. Having a clear-cut corporate plan to guide IS planning efforts
3. Having a clear, concise, formal planning procedure
4. Deciding on an appropriate planning horizon
5. Anticipating likely changes in information technology (and environmental changes) which might affect the strategic IS planning process
6. Being able to obtain sufficiently qualified personnel to do a proper job
7. Having free communication and commitment to change throughout the organization
8. Investing sufficient "front-end" time to ensure that all planning tasks and individual responsibilities are well understood
9. Taking into account the people and politics side of the strategic IS planning process
10. Good user-IS relationships

IS planning method (categorical scale)
- Bottom-up
- Top-down
- Combination of both

Because the field of IT is changing rapidly, the ability to anticipate, identify, and assimilate new information technologies is important (Raghunathan & Raghunathan, 1994) for continued competitiveness. Related to new technologies is the ability to obtain sufficiently qualified personnel to do a proper job. Other factors such as having free communication and commitment to change, and managing the people and politics, have been found to be important in systems implementation (Orlikowski, 1993) and can be applied to IS planning. In addition, investing sufficient "front-end" time to ensure that tasks and responsibilities are understood can help smooth out "kinks" in the IS planning process.

Another important factor in IS planning is good user-IS relationships. Earl (1993) found poor user-IS relationships to be the fifth most commonly cited factor of unsuccessful IS planning exercises. Various researchers (Cash et al., 1992; Teo & King, 1997) have emphasized that close relationships between business and IS staff are necessary to ensure that IS plans support business strategies.

All the research variables were reviewed by five senior IS practitioners (three from the courier service industry and two from manufacturing) and three IS faculty members. They also pretested the survey questionnaire to resolve ambiguities and enhance comprehensibility.

RESEARCH HYPOTHESIS

The above literature review suggests that the relationships between the determinant variables and IS planning benefits are often investigated indirectly, and linearity is often assumed. However, due to the inherent complexity of organizational phenomena, relationships among variables are likely to be nonlinear and complex. Hence, the assumption of linearity, though possible, is often questionable. It is our thesis that determinant variables do not necessarily correlate with benefits in a linear manner. For example, top management support can only do so much for IS planning benefits, beyond which any increase in top management support will result in a diminishing rate of return. If that is the case, then there exists a nonlinear relationship.

Our assumption of nonlinearity is reinforced by the existing literature which indicates that planning involves organizational learning (Auer & Reponen, 1997; Goold, 1996) and that learning is nonlinear (see Argote, Beckman, & Epple, 1990; Baloff, 1971; Yelle, 1979; Givon & Horsky, 1990; and Little, 1979). Because organizational learning that takes place during the IS planning process may affect the level of benefits achieved, and because learning itself is a nonlinear process, the relationships among variables are likely to exhibit nonlinear characteristics. We therefore assume nonlinearity in our models. The basic research hypothesis for this study is as follows:

Hypothesis: There are significant nonlinear relationships between the determinant variables (defined in terms of organizational and implementational variables) and IS planning benefits.

DATA ANALYSIS

As in most empirical studies, there were missing values for some of the variables. This problem was particularly serious when summation variables were constructed from the data, because for the case in which any variable in the summation was missing, the entire summation would also be missing for that case. Therefore, in these cases, the average values were used for missing values, a procedure adopted by Schroeder, Anderson, Tupy, & White (1981) and Sum et al. (1995) in their studies on MRP benefits and costs. No cases had to be discarded because of a high proportion of missing values.

Our usable sample of 65 firms, though relatively small, is larger than that used in previous IS planning research in Singapore. Pavri and Ang (1995) had 34 firms, and Teo et al. (1997) had 58 firms. Sum et al.'s (1995) study on MRP benefits had 52 firms. A larger sample admittedly would generate more robust results. However, we used ACE, which is a nonparametric statistical tool (De Veaux, 1989) that does not require assumptions about the normality of data distribution. Hence, our sample of 65 firms is adequate for data analysis.

Factor analysis (principal component method with varimax rotation, and selection of factors with eigenvalues greater than one) was used to reduce the large number of items to a parsimonious set before regression analysis. In general, the sample should be four or five times the number of items to be factor analyzed. Hair, Anderson, and Tatham (1987, p. 237) suggested that this ratio is somewhat conservative, and that it is permissible to work with a lower ratio, provided that the findings are interpreted with caution. We had 30 items for determinant variables (of which 11 were categorical items) and eight items for benefit variables. Separate factor analyses were conducted on the 19 items for determinant variables (excluding the categorical variables) and on the eight items for benefit variables. The ratios of sample size to number of items factor analyzed are 3.42 and 8.13 for determinant and benefit variables, respectively. These ratios are adequate provided that the findings are interpreted with caution. Moreover, ours is an exploratory factor analysis, and the need to stick to the suggested ratio, though desirable, is not that crucial. Table 3 shows the results of factor analyses for the determinant and benefit variables.

The results confirmed the unidimensionality of the items used to measure firm size and IS sophistication. The implementational variables loaded onto four distinct constructs. They are proper planning procedures, communication culture, technology forecasting, and top management support. The benefits (dependent) variables loaded onto three distinct constructs. They are improved competitiveness, improved operations, and improved resource management. Because this research is exploratory, all constructs were retained rather than reducing or eliminating any of them. Reliability assessment confirmed that the reliability for each of the constructs is equal to or above Nunnally's (1978) recommended Cronbach alpha value of .60.

Hence, there were three dependent variables for which regression models had to be developed separately using ACE. In carrying out ACE analysis, all categorical variables such as industry type and organizational structure were dummy coded. The Appendix contains a brief discussion of the ACE algorithm (see Breiman & Friedman, 1985, and De Veaux, 1989, for in-depth details).

Modeling IS Planning Benefits

The approach used to generate the ACE transformations was forward stepwise inclusion of variables with backward stepwise deletion after each step. Using the variables from the ACE models finally selected, OLS multiple regression was conducted to see how much ACE had improved the models. For example, the ACE adjusted R^2 for the model on improved resource management was about 56 percentage points better than the linear model. In all cases, ACE models produced better p-values than the corresponding linear models. Table 4 shows the variables

Table 3: Factor analysis.

Factor Description	Variable Description	Loading
Organizational variables		
Firm Size (α =.90)	Company revenues	.86
	Total number of employees	.86
	Total IS expenditure	.93
	Total number of IS-related employees	.84
IS Sophistication (α = .77)	Alignment of IS and business plans	.69
	Capital allocation criteria for IS projects	.81
	Objective setting for IS personnel	.75
	Computer operations	.63
	Feasibility assessment of IS projects	.74
Implementational variables		
Proper Planning Procedures (α = .72)	Having a clear, concise, formal, planning procedure	.85
	Deciding on an appropriate planning horizon	.75
	Having a clear-cut corporate plan to guide IS planning efforts	.72
Communications Culture (α = .66)	Taking into account the people and politics side of strategic IS planning process	.77
	Investing sufficient "front-end" time to ensure that all planning tasks and individual responsibilities are well understood	.66
	Good user-IS relationships	.61
	Having free communication and commitment to change throughout the organization	.60
Technology Forecasting (α = .60)	Being able to obtain sufficiently qualified personnel to do a proper job	.79
	Anticipating likely change in information technology (and environmental changes) that might affect the strategic IS planning process	.73
Top Management Support	Getting top management support for the planning efforts	.81
Benefits		
Improved Competitiveness (α = .78)	Larger market share	.89
	Improved competitive position	.79
	Greater ability to meet changes in the industry	.67
Improved Operations (α = .67)	Improved productivity	.79
	Improved quality in products/services	.70
	Sound technology path and policies	.57
Improved Resource Management (α = .60)	Efficient and effective management of IS resources	.84
	Improved internal coordination	.64

Table 4: ACE models.

Determinant Variables		Benefit Variables: Improved Competitiveness	Improved Operations	Improved Resource Management
Organizational				
Organizational Structure (Physically Centralized)				.0038 *p*=.0253
Operational Structure (Functional)			.0274 *p*=.0083	
Computer Configuration (Physically Dispersed)			.0270 *p*=.0073	
Systems Development (Functionally Centralized)			.0111 *p*=.0110	.0811 *p*=.0268
Firm Size				.0321 *p*=.0000
IS Sophistication		.4832 *p*=.0000		.0160 *p*=.0032
Implementational				
IS Planning Method (Bottom-Up)				.0172 *p*=.0256
Proper Planning Procedures				.1948 *p*=.0000
Communications Culture			.1684 *p*=.0000	
Technology Forecasting			0.0885 *p*=.0019	0.0116 *p*=.0020
Top Management Support			.0861 *p*=.0008	.2310 *p*=.0002
Model R^2	ACE	.4832	.4809	.6386
	(Linear Regression)	(.2130)	(.3277)	(.1489)
Model adjusted R^2	ACE	.4750	.4272	.5870
	(Linear Regression)	(.2005)	(.2581)	(.0273)
Model *p*-value	ACE	.0000	.0000	.0000
	(Linear Regression)	(.0001)	(.0006)	(.3021)
Sample size (*N*)		65	65	65

for the final ACE models and the corresponding R^2, adjusted R^2, and *p*-values, and comparisons with the OLS linear models.

Note that the figures above the *p* values for the determinant variables (organizational and implementational) represent the regression coefficients resulting from the ACE analysis. Also, because categorical variables such as organizational structure, operational structure, computer configuration, systems development, and IS planning method, are dummy coded, only the relevant values (e.g., physically centralized for organizational structure) that are significant in the ACE analysis are shown.

RESULTS AND DISCUSSIONS

The optimal transformations for the variables in the three benefit models (obtained directly from ACE outputs) are shown graphically in Figures 1 to 3. These results supported our hypothesis that there exists significant nonlinearities in the relationships.

In interpreting the models, it should be noted that the transformed values of the independent variables are positive correlates of their corresponding pretransformed dependent measures. This is so because all transformations of the dependent variables are nondecreasing functions and all parameter estimates of the independent variables are positive (see Table 4 and the Appendix). Therefore, we can interpret the transformed value axis (y-axis) of the independent variable transformation plots as if it is the corresponding "dependent variable" axis.

In other words, Figure 1b can be interpreted as showing the relationship between IS sophistication on the x-axis (observed) and improved competitiveness on the y-axis (transformed). Likewise, Figures 2b, 2c, and 2d show the relationships between communications culture, technology forecasting and top management support, and improved operations. In contrast, Figure 2a presents the overall effect of the statistically significant determinant variables on improved operations. Simply put, Figures 1a, 2a, and 3a show the overall effect of the statistically significant determinant variables (in Table 4) on each of the dependent variables, respectively. The remaining figures (i.e., Figures 1b, 2b to 2d, 3b to 3f) show the individual effects of each determinant variable on the corresponding dependent variable.

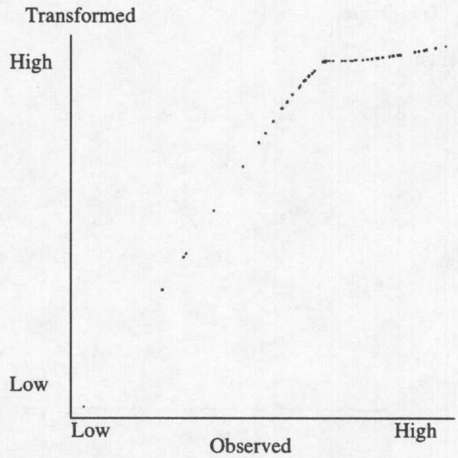
For constructs that are categorical (e.g., industry type, organizational structure), significant results are indicated either by two dots at the low/low and high/high ends of the graphs respectively, or by two dots at the low/high and high/low ends of the graphs, respectively, depending on whether the relationship between that particular categorical variable and the dependent variable is positive or negative. In this paper, all categorical variables that are statistically significant show positive relationships with the dependent variable(s). Note that in the interest of saving journal space, plots for categorical variables are omitted because they do not convey much information.

Improved Competitiveness

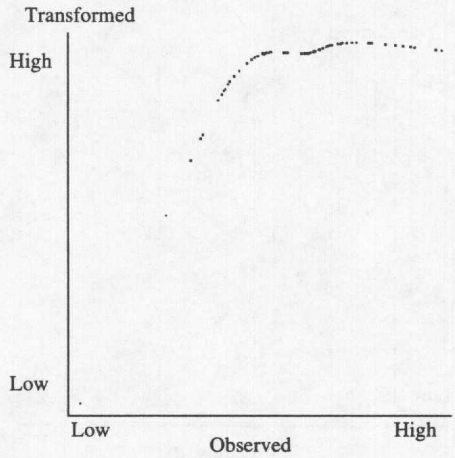
Table 4 and Figure 1 show that IS sophistication affects improved competitiveness positively, and that the latter is not significantly related to other determinant variables. An examination of the nonlinear transformation of the dependent variable (Figure 1a) reveals that the model explains only how improved competitiveness may be achieved with higher levels of IS sophistication up to a certain point. The almost flat portion in the higher part of the transformation means that IS sophistication probably does little to predict improved competitiveness in this range. One possible reason is that beyond an optimal level of IS sophistication, other factors may become more important in influencing competitiveness. Such factors may include the need for business process reengineering, forging strategic business alliances, leveraging unique assets, and the match between industry characteristics and a firm's strategic orientation. At higher IS sophistication levels, IS planning may be a necessary but not sufficient condition for further improved competitiveness.

Figure 1: ACE results for improved competitiveness benefit.

a. Improved Competitiveness



b. IS Sophistication

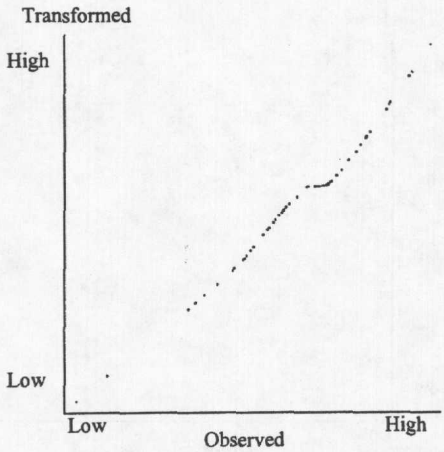


IS sophistication

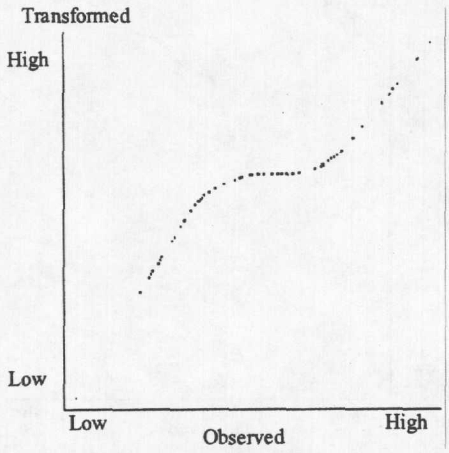
The transformed variable of IS sophistication (Figure 2b) can be interpreted as follows. The ability to allocate resources (e.g., hardware, software, and skilled manpower) to software projects is important. Although various empirical estimation (software allocation) models exist for allocating resources, no one model is appropriate for all classes of software and in all development environments. IS personnel have to choose the appropriate model and interpret the results obtained judiciously, because models are at best a guide. Therefore, much depends on the knowledge and expertise of IS personnel. Also, much has been said on the importance of aligning IS objectives with those of the overall business. The aim of such

Figure 2: ACE results for improved operations benefit.

a. Improved Operations



b. Communications Culture

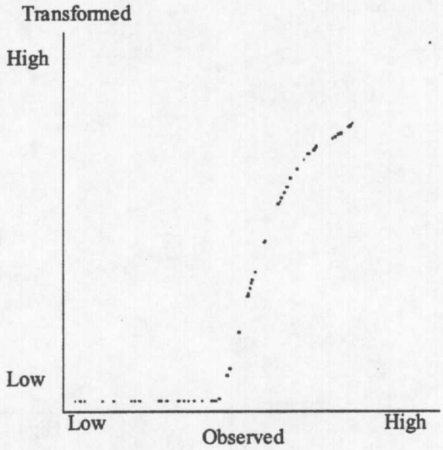


alignment is to enable the IS function to better support business strategies by ensuring that IS projects serve business needs.

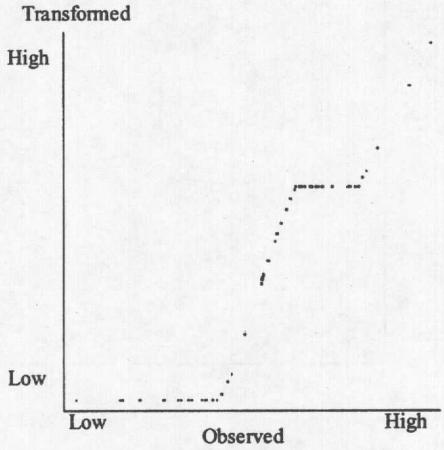
Many IS projects have fallen prey to unrealistic expectations and to large project overruns in both time and money (Lederer & Prasad, 1992; Frey, 1994). As such, it behooves a firm to conduct proper feasibility studies for systems it intends to develop so that the resulting systems will be organizationally relevant and technologically feasible. Computer operations have to be monitored. Otherwise, inefficiencies that negate any computerization benefits may result. From management's perspective, it is especially useful to set highly targeted individual objectives for IS personnel that would allow management to monitor work

Figure 2: (continued) ACE results for improved operations benefit.

c. Technology Forecasting



d. Top Management Support



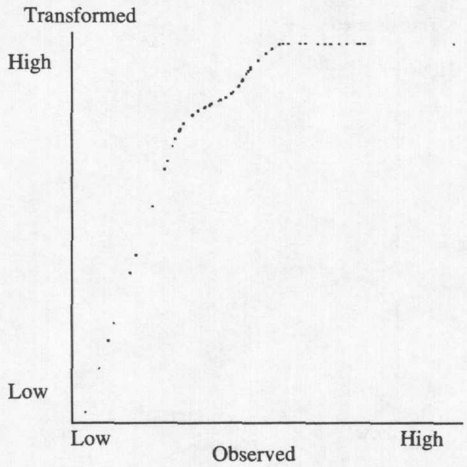
Note: Categorical variables that have significant positive relationships with improved operations are operational structure (functional), computer configuration (physically dispersed), and systems development (functionally centralized). The plots for these variables are not shown as they are not informative.

progress and design appropriate compensation packages to reward IS personnel who are productive. Hence, some level of IS sophistication is desirable.

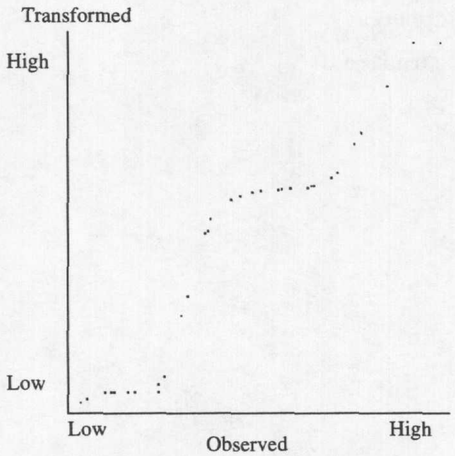
However, at higher levels of IS sophistication, competitiveness stagnates and may even decrease (Figure 1b). One possible reason is that when IS sophistication rises to a high level, any further benefit may be canceled out by bureaucratic

Figure 3: ACE results for improved resource management benefit.

a. Improved Resource Management



b. Firm Size

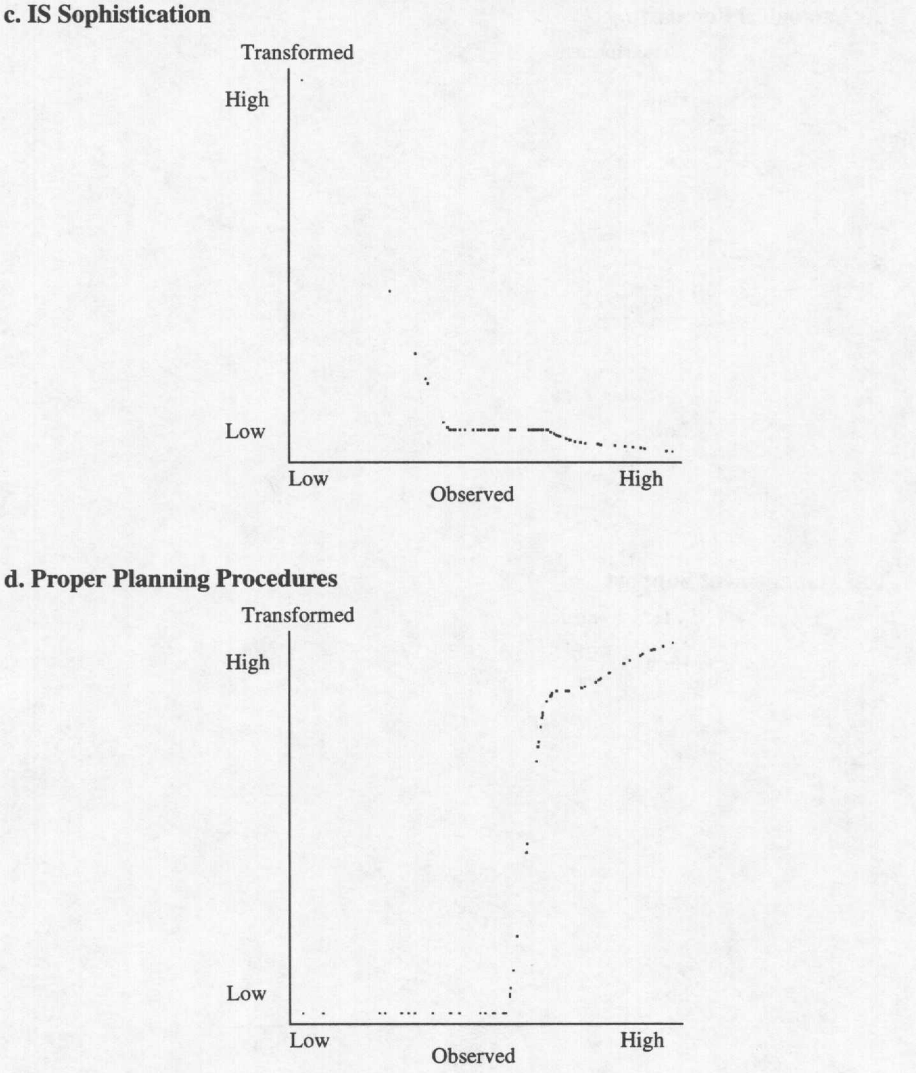


bottlenecks, overly formal rules, and procedures. For example, feasibility assessment could be unduly hampered by too much emphasis on risk identification and analysis. Allocation of computing resources could be less than optimal if overly refined estimation models are used. Furthermore, with highly formal and stringent rules and procedures that result from increased IS sophistication, it may take the organization longer to respond to environmental changes. As a consequence, this can result in lost opportunities and decreased competitiveness.

Improved Operations

Table 4 shows that operational structure, computer configuration system, system development, communications culture, technology forecasting, and top management

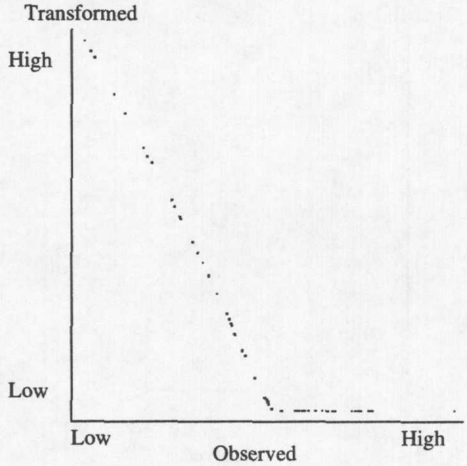
Figure 3: (continued) ACE results for improved resource management benefit.



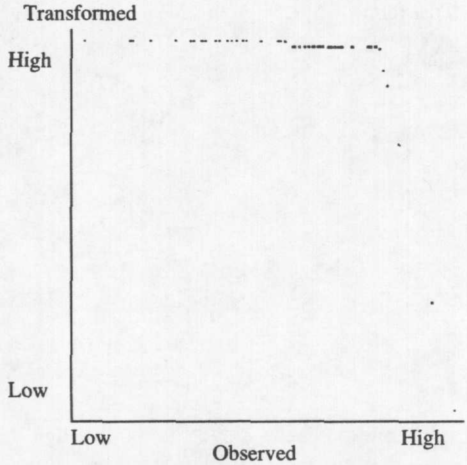
support are important determinant variables of improved operational effectiveness. These variables are plotted in Figure 2 (with the exception of categorical variables). The transformation of improved operations is nonlinear (Figure 2a). The midway plateau indicates that, over a certain range, we cannot predict the improved operations benefit from the combination of determinant variables. Also, it is unclear how the ranges of observed benefits are related to that combination. One probable explanation for the transformation is this. An audit is usually conducted midway through the IS planning process to ascertain if it is on the right track. Are new opportunities being identified? Is systems integration effectively undertaken? Are business functions adequately supported by the systems? Are

Figure 3: (continued) ACE results for improved resource management benefit.

e. Technological Forecasting



f. Top Management Support



Note: Categorical variables that have significant positive relationships with improved resource management are organizational structure (physically centralized), systems development (functionally centralized), and IS planning method (bottom-up). The plots of these variables are not shown as they are not informative.

computing resources allocated efficiently? Has the decision-making process improved? During this period, improved operations could vary because many adjustments, both systems and people, are made.

Operational structure

The results suggest that firms organized along functional lines achieve higher operational effectiveness than those organized under other organizational forms (e.g., product, matrix or conglomerate, which failed to achieve significance). One plausible reason is that by dividing the organization into specific functions, activities become more focused, thus resulting in overall improved operations. The functions and objectives of each division are better understood with fewer overlapping tasks. The personnel within each department are better able to concentrate on achieving task requirements and improving core competencies, thus improving productivity and quality of outputs. Managers are more focused on developing better policies and directions for their divisions to achieve overall company objectives.

Computer configuration system

Physically dispersed computer configuration systems are significantly associated with improved overall operations. Such a system consists of computers deployed in different locations. These computers, which function autonomously, are not connected to a common network. This is counterintuitive, as one would expect a distributed system where computers are connected to a common network to be instrumental to improved operations.

One possible explanation is that when organizations are functionally divided, these divisions operate as self-contained entities. The operations in each functional area are specific and focused, so are the computer configurations. For example, R&D and design divisions are better served with workstations equipped with powerful graphics and mathematical processing capabilities. So instead of having a common network, most organizations are likely to have clusters of specifically tailored systems. This is consistent with the nature of our sample, which consists of large to very large organizations with formal IS planning processes.

Systems development

The results show that centralization of systems development, especially those that are of core importance to the organization or those that cut across functional lines, are associated with improved operations. Although computing resources are increasingly placed in functional areas, the control of these resources often resides in the central IS function. This permits standards to be established and enforced, thereby reducing problems relating to systems incompatibility and data integrity. As a consequence, improved operations may ensue.

Communications culture

Figure 2b suggests that a developed communications culture is associated with improved operations. Also, the figure shows a plateauing of operations benefit over a range of communications culture scores. Two explanations can be offered. First, when some form of communications culture is present, improved operations can be achieved up to a certain point. However, to progress beyond that, more effective coordination, information gathering, information dissemination, and feedback mechanisms are needed for more complex operations. Strategic IS planning requires accurate information and the cooperation of individuals within and among functional areas. This means managing conflicts and unambiguously defining the various roles. Furthermore, existing work processes may have to be reconfigured to obtain full benefits of the system. As such, communication problems and conflicts between various stakeholders need to be properly managed to ensure that overruns in both time and money do not occur. Therefore, the people involved must be made to feel part of the change. Hence, an effective communications culture is essential.

The second explanation can be derived from Hebbs' (1949) principle of cumulative learning. He stressed the need to acquire the fundamental perceptual elements, simple associations, and rudimentary conceptual sequences, before learning can proceed with increasing swiftness and complexity. In IS planning, this means having a basic communications structure, where people from different departments first learn how to use that structure to support business operations, and improve productivity and quality of work. During this plateau stage where the organization forms its own communications culture, few benefits are obtained. Beyond a certain threshold, the learning process accelerates and more benefits can be achieved.

Technology forecasting

The transformed variable of technology forecasting (Figure 2c) can be interpreted as follows. It is important for firms to have a pool of highly qualified IS personnel who undertake the technical aspects of IS planning. These IS personnel are also important in assessing and assimilating new technology, which is a more complex task than it might initially appear to be. It takes a while before the pool of IS personnel builds up its expertise in upstream and downstream portions of the IS planning process for operations benefits to be realized, especially when the business solutions for each organization are unique. Distinct IS expertise facilitates the process of innovative technology and adoption, and the development of complex and flexible systems which are necessary for productivity and improved products/services.

Top management support

Figure 2d shows the transformed variable of top management support for the IS planning effort. At lower support levels, there are no effects on improved operations, but beyond that the benefit of top management support can be seen before another plateau is reached. Top management support is widely acknowledged to be crucial in successful systems implementation and IS planning (Raghunathan, 1992; Thong, Yap, & Raman, 1996). Low support level occurs when the IS planning process is handicapped by unavailability of critical resources (e.g., people, funds, and equipment). In cases of low support, top management may either overlook the problem or be unwilling to provide the resources, perhaps because other crucial projects may be contending for these resources. Once top management commits and allocates these resources to the IS planning process, improved operations can be expected.

At higher levels of management support, operational effectiveness stagnates (see second plateau in Figure 2d). This could be due to overzealousness on the part of top managers who may want to have a more direct say in the IS planning process, something that can be counterproductive. This is where the IS steering committee usually puts top management's role in perspective. Top management ideally should act as a driver of the IS planning process, creating goals, values, and visions, but not as a dominant participant. The clarity of goals and purpose that ensues results in greater operational effectiveness.

Improved Resource Management

Improved resource management is affected by organizational structure, systems development, IS planning methods, firm size, proper planning procedures, technology forecasting, top management support, and IS sophistication (Table 4). These variables are plotted in Figure 3 (with the exception of categorical variables).

The flat portion of the transformation curve shows that improved resource management cannot be predicted from the combination of independent variables over this range (Figure 3a). The transformation curve is explained as follows. Firms with IS departments that are very mature are usually those that operate in a highly competitive environment and use emerging technologies. As competitive pressures and emerging technologies are not dependent on the determinant variables examined in this study, the observed benefit could, therefore, vary.

Organizational structure

The relationship between organizational structure (in terms of physical centralization) and improved resource management is significant. Hence, physical centralization of an organization helps improve resource management. One plausible explanation is that having the company's operations carried out from one location makes it easier to manage resources and coordinate the various functional areas. Another plausible explanation is that Singapore is a very small country, which makes it more economical to house many operations under one roof.

Systems development

The explanation on systems development (under subsection: Improved Operations) applies here too. In other words, centralization of systems development also leads to improved resource management. This improvement could result from the ease with which standards are established and enforced, thereby reducing problems relating to systems incompatibility and data integrity.

Firm size

Firm size seems to affect improved resource management. The transformed variable shows four distinct steps or ranges of firm sizes (see Figure 3b). Improved resource management does not take place until a firm is reasonably large to undertake IS planning on a meaningful scale. That probably explains the first plateau. As firm size increases beyond a certain point, firms have to configure their organizational activities to manage the growing complexities of operations. That probably explains the second plateau. Another explanation could be that associated with Hebbs' (1949) learning curves (see Communications culture).

IS sophistication

Although IS sophistication improves competitiveness, it hampers resource management (Figure 3c). Resource management seems to decrease with increased IS sophistication. Increased IS sophistication intuitively should result in improved resource management due to better alignment between business and IS plans, and more effective allocation of resources for IS projects. However, this effect may be foiled by continual corporate reorganization brought about by the need to respond rapidly to changes in the business environment. So, increasing IS sophistication is directed at improving competitiveness, even though it may result in less efficient activity coordination and computing resource allocation. Over time, organizational learning takes place, and firms learn how to handle competitive pressures and manage resources better. This explains the leveling off of the curve at the higher levels of IS sophistication.

IS planning method

The results suggest that a bottom-up IS planning approach leads to improved resource management in contrast to the top-down, or a combination of bottom-up and top-down approaches. One probable reason is that the environment may be too turbulent for other approaches to work successfully because conditions change before the systems are completed, thereby resulting in wastage of resources. Furthermore, in some firms, top management may not know enough about IT to provide directions for IS planning (Grover, 1991).

In contrast, the focus of the bottom-up approach is on the improvement of information systems eventually developed as well as the "empowerment of workers so that they can co-determine the development of the information system and of their workplace" (Clement & Van den Besselaar, 1993, p. 29). Users are then better prepared and more confident in using the IS resources at their disposal. Users are also prepared to perform activity coordination because the systems developed have taken into account the contexts and constraints of the various functional areas. In other words, bottom-up planning helps to ensure that valuable inputs of users are obtained and taken into account during IS planning. This leads to improved resource management because the developed systems take into account users' needs and organizational objectives.

Proper planning procedures

Proper planning procedures help improve resource allocation and coordination. However, this is not easily achieved. The transformed Figure 3d shows that, in order to achieve improved resource management, proper planning procedures are necessary to set clear directions for optimizing resource utilization and achieving internal coordination. For example, once a systematic linkage between the IS and business plans is established, commitments regarding the order in which new applications are to be developed can be made without functional units contending for computing resources. So, when the proper planning procedures are articulated and clearly understood by both the IS and line staff, improved resource management will accrue. However, an organization is an organic entity with business and institutional needs that change over time. Changing needs necessitate a reexamination of planning procedures (e.g., resetting the planning horizon in light of new technologies), and that probably explains the tapering of improvement in resource management at the upper range.

Technology forecasting

In contrast to the Communications culture subsection, having highly qualified IS personnel and the ability to forecast problems and needs seem to work against the benefit of improved resource management (Figure 3e). One plausible explanation is this. Though a pool of highly qualified IS personnel can chart sound technology paths and policies, most of them simply rely on vendors to keep them aware of new technology (Clarke, 1992). In fact, very little technology forecasting was undertaken. This led to a reactive rather than a proactive approach. A prudent and sound course of action would be to forecast technological changes, and then use these forecasts to plan the purchase of computing resources. Instead of proceeding from forecast to action, most IS managers are influenced by vendors' hard sell.

Most of the companies in our survey did not follow either a "leading-edge" or "technology-push" approach. Rather, they seem to have a "lagging-edge" philosophy with regard to technology forecasting. They acquired proven technology that was geared to efficiency enhancement (which initially worked well), but when business needs changed, their technology and resource management suffered. This may explain the negative slope of Figure 3e. The decreased level of resource management reaches a plateau when users succeeded in adapting lagging technology to meet changing business and institutional needs.

Top management support

Likewise, for top management support, the transformed plots are not in line with expectations. At very high management support levels, resource management benefit is reduced (Figure 3f). Perhaps when top management is too involved, a lot of red tape occurs. Every minute detail in terms of resource allocation and usage has to pass top management scrutiny or approval. This may hamper decisions made by the middle level managers. Although it is healthy for top managers to sit in meetings and spend more time with employees, it is unhealthy when top managers turn into interrogators. Top management support should consist of the following: showing interest, providing the necessary resources, and providing leadership. It is counterproductive when top managers directly control the IS planning process because it is usually not their forte.

LIMITATIONS

There are three main limitations of this study. First, the sample is relatively small, though much bigger than previous research on IS planning in Singapore. As this research is primarily exploratory and represents the first use of the ACE technique in IS research, this limitation is not serious. Second, in the interest of parsimony, we have selected a limited number of determinants and benefits of IS planning from past research literature. Future research can investigate the use of other variables as independent and dependent variables. Third, the use of a single respondent per firm may result in common source bias. However, we have mitigated this limitation by ensuring that respondents are senior executives in the firm. It is conceivable that such executives, due to their experience, are likely to give more valid and reliable responses to the questions asked.

IMPLICATIONS

The ACE algorithm was used to uncover meaningful and insightful relationships between IS planning benefits and determinant variables. In particular, the study revealed significant nonlinear relationships that are useful for IS managers undertaking IS planning. OLS regression is not able to do this. The relationships and discussion of the implications are summarized as follows:

1. *IS sophistication* seems to be an important factor in improved competitiveness.This is expected because IS sophistication determines the extent to which an organization can effectively reconfigure its work processes. But at higher levels of IS sophistication, bureaucratic bottlenecks may set in. As such, the organization should subject its IS planning process to periodic audits to ensure that it is not fettered with overly formalistic rules and procedures.

   Increased IS sophistication seems to affect resource management negatively. Firms could be directing their IS sophistication towards increasing their competitiveness, even though this may result in less efficient resource allocation. In this case, increased competitiveness takes precedence over resource management. In the short run, this may be necessary, but this is not a desirable state in the long run because an organization needs to manage both competitive pressures and resources effectively in order to be successful.

2. *Developed communications culture* leads to improved operations. However, an organization can only continue improving operations if communications culture evolves to higher levels to cope with the complexities of strategic IS planning. Therefore, effective coordination and feedback mechanisms must be in place.

3. *Technology forecasting* requires a pool of highly qualified IS personnel with the context-specific IS expertise necessary to bring about improved operations. Such context-specific IS expertise needs to be at a certain minimum level before it can effectively engage in technology forecasting. This is captured by the nonlinear relationship between technology forecasting and improved operations. Computing resources acquired as a result of the vendors' hard sell may not be the best to support the organization's operations. As such, a longer period of adjustment is necessary before improved operations accrue.

   Technology forecasting affects resource management negatively. One likely explanation is the dependence of IS personnel on hardware and software vendors—a dependence that influences IS personnel to buy on recommendations. An IS manager undertaking technology forecasting needs to develop a strong, systematic linkage between the business plan and the technology required to support the plan. Development of systems can then be undertaken to fulfill specific business needs. Done this way, computing resources will be put to better use. If any purchase is required, a Request for Proposal (RFP) (containing the dimensional specifications) can be prepared to manage the vendor contracting process so that the eventual product is one that fits the corporate plan. IS personnel therefore need to learn how to undertake technology forecasting and purchase new technology that is relevant to the organization's operations.

4. *Top management support* affects improved operations positively only when IS planning is not hampered by unavailable resources and top management overinvolvement. The former occurs at lower management support levels, usually at the start of the IS planning process, and the latter at higher management support levels, when top management wants to have direct control of the IS planning process. An overly zealous top management can affect benefits from improved resource management negatively. One can draw a valuable lesson here: Top management should commit the necessary resources and stick to its role as the driver of the IS planning process, rather than as a controlling participant.

5. *Firm size* does not seem to affect improved competitiveness and improved operations benefits. An organization does not have to be large to be competitive and operationally effective (i.e., producing high-quality products, improved productivity). However, firm size seems to affect resource management. Improved resource management occurs only when an organization is of sufficient size to undertake IS planning on a meaningful scale. As the organization expands, its work processes have to be reconfigured and streamlined before it can effectively manage internal coordination and IS resources.

6. *Industry type* does not seem to improve competitiveness, operations, and resource management. It appears that the benefits of IS planning for both service and manufacturing companies are determined by organizational factors rather than type of industry. Intuitively, industries may differ in terms of their information intensities, and consequently, the extent of IT use. It is possible that such differences in information intensities are narrowing, with the increased proliferation of IT in all sectors of the economy. As a consequence, industry type may not affect IS planning benefits. This explanation is consistent with previous research that found that industry type does not affect the importance of IS planning (Pavri & Ang, 1995). Likewise, Premkumar and King (1991) did not find any significant differences in planning effectiveness (benefits) among firms in different industries. Hence, it is likely that it is not the industry type per se, but other organizational characteristics that determine whether the benefits of IS planning are achieved.

7. In terms of the determinants for the three benefit variables, improved competitiveness appears to be greatly affected by IS sophistication (as evident by the small *p*-value of .0000), with other independent variables showing insignificant results. One possible reason is that IS sophistication influences the extent to which IT applications are being used for strategic purposes.

8. In comparing the determinants for improved competitiveness with improved operations and improved resource management, it is evident

that it is more difficult to find a determinant variable for the former than for the latter two benefits. One likely reason is that there are many factors that influence the competitiveness of the firm, whereas the impact of IT on improved operations and improved resource management may be more salient.

CONCLUSION AND FUTURE RESEARCH

This study provides a significant methodological contribution by setting the groundwork for using ACE in IS research. Future research could use ACE to study other aspects of IS planning as well as other IS research topics for which linear and nonlinear relationships are of interest. This may lead to a better understanding of the complex relationships (both linear and nonlinear) between the independent variables and the dependent variables.

In particular, because the findings suggest significant nonlinear relationships between the determinant and benefits variables, it is imperative that business and IS managers comprehend and manage these relationships effectively so as to derive maximum benefits from IS planning. Although the detailed interpretations of the nonlinear relationships are, in some sense, speculative, such results still provide important insights and avenues for further research.

Future research might include case studies to capture the context-specific features, activities, and events of each organization that cannot be captured through ACE modeling. Such studies are particularly useful when "how" and/or "why" research questions need to be answered. Although ACE transformations may reveal novel relationships between variables, the dynamic processes involving these variables can only be captured through detailed case analysis. Surveys can provide important conceptual frameworks or models that can be used to guide detailed case studies. Other avenues for future research include expanding the list of determinant and benefit variables, increasing the sample size, and examining such relationships in a different cultural context. [Received: June 19, 1997. Accepted: June 12, 1998.]

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APPENDIX

Alternating Conditional Expectations (ACE)

The ACE algorithm (Breiman & Friedman, 1985) is a nonparametric tool for finding transformations. The ACE algorithm produces the best fitting additive model by estimating individual optimal smooth transformations for the dependent and independent (predictor) variables to maximize the correlation between the dependent variable and the variable of the fitted values.

Unlike other empirical methods, the ACE transformations are unambiguously defined and estimated without the use of heuristics, restrictive distributional assumptions, or restriction of the transformation to a particular parametric family. Often, ACE produces models that have a much superior fit compared to those generated using standard regression techniques such as Ordinary Least Squares. More details about using ACE can be found in Fox and Long (1990).

ACE Example

This example will demonstrate the effectiveness of ACE by attempting to recover the transformations for individual variables in the following equation used to construct *Y*:

$$Y = \log[3\sin(1.3A) + \text{abs}(B) + C^2 + (D^3/9) + E + 10] - 8, \qquad \text{(A1)}$$

where *A*, *B*, *C*, *D*, and *E* are independent samples of 100 observations drawn from the normal distribution with mean 0 and variance 1. Note that relationship (A1) above can be re-expressed as:

$$e^8 \exp(Y) = 3\sin(1.3A) + \text{abs}(B) + C^2 + (D^3/9) + E + 10. \qquad \text{(A2)}$$

Thus, if we are simply given the data values for *Y*, *A*, *B*, *C*, *D*, and *E*, without knowledge of functional relationship (A1), we might try to plot *Y* individually against the independent variables *A*, *B*, *C*, *D*, and *E* so as to gain some insights on the pairwise relationships, yielding the graphs in Figure A1. Note that the plots in Figure A1 do not suggest any obvious transformation for either the dependent or independent variables, even though *A*, *B*, *C*, *D*, and *E* are statistically independent.

ACE Regression

If we now invoke ACE on the given data set, ACE will provide an output of individual transformations for the variables as shown in Figure A2. ACE's suggested graphical transformations for the variables are shaped exponential for *Y*, sine for *A*, absolute-value for *B*, square for *C*, cubic for *D*, and linear for *E*, which are exactly the corresponding functions in relationship (A2).

Note that the transformations do not provide any information on the scales of the transformed variables (e.g., 3 for sin (1.3*A*)) or any shift in the origins for the transformed variables (which would affect the intercept +10). This is because the scaling of an independent variable does not affect the fit of the corresponding regression model, and any translational shift in the origins will be absorbed into the constant term in a regression. We therefore need not be concerned with the markings on the scale for the ordinate (*y*-) axis in a plot of the suggested ACE transformation for a variable. That is, the origin for the *y*-axis can be fixed anywhere and the unit of measurement for the *y*-axis is arbitrary.

Figure A1: *Y* vs. *X*s.

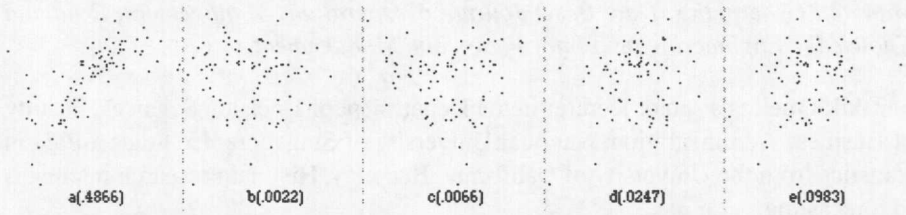
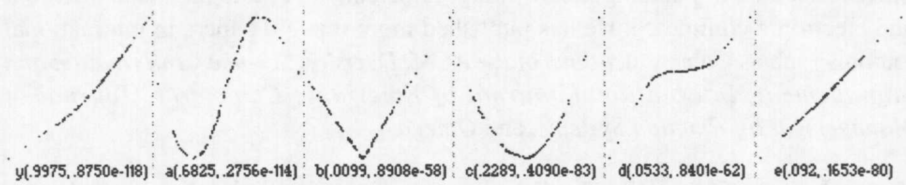


Figure A2: ACE transformations.



In addition, the suggested ACE transformations are constructed such that a larger transformed value for an independent variable will be associated, everything else being equal, with a larger value of the transformed dependent variable. In other words, if we regress the transformed dependent variable on all the transformed independent variables, all estimated parameter coefficients for the transformed independent variables will be positive. Further, by default ACE ensures that the transformed value of the original observed maximum *y* value is no smaller than the transformed value of the original observed minimum *y* value. ACE can also optionally force the transformation of *y* to be nondecreasing.

The ACE model has an R^2 of .994, which is short of 1.0 because ACE, being a numerical procedure, is not perfect even for a deterministic model. However, note that the R^2 of .994 is considerably better than .637 as obtained using OLS. It is important to note that in theory ACE cannot fit worse than ordinary regression, because if no transformation is indeed necessary (i.e., the ordinary regression model is exactly true), then ACE would simply suggest nearly linear transformations for all variables (much like the transformation for *E* in Figure A2)—OLS is ACE restricted to linear transformations.

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