Executive Support Systems and Learning: A Model and Empirical Test

BETTY VANDENBOSCH AND CHRISTOPHER A. HIGGINS

BETTY VANDENBOSCH is the Lewis–Progressive Assistant Professor in the Management Information and Decision Systems department of the Weatherhead School of Management at Case Western Reserve University. She holds a Ph.D. from the Western Business School at the University of Western Ontario. Dr. Vandenbosch has presented papers at various national and international conferences and has published in *Accounting, Management and Information Technologies*, and *Information Systems Journal.* She also has several years experience as a management consultant with McKinsey & Company, and continues to consult to several organizations on management information issues. Her current research interests focus on executive information, and the impact of technology on individual and organizational learning.

CHRISTOPHER A. HIGGINS is an Associate Professor in the Information Systems group at the Western Business School, at the University of Western Ontario. Dr. Higgins has published over forty articles in journals including *Communications of the ACM, Administrative Science Quarterly, Information Systems Research, MIS Quarterly, Journal of Applied Psychology, Sloan Management Review*, and *ACM Transactions on Office Information Systems.* He has also coauthored two books. His specific research interests include computerized monitoring, organizational champions, and telework. Two of Dr. Higgins's Ph.D. students (Rebecca Grant and Betty Vandenbosch) have won international thesis competitions for their research. Dr. Higgins is currently the coholder of the Imperial Life Professor Chair.

ABSTRACT: A model of the relationships among executive support systems (ESS), learning, and performance is developed. This model describes the impact of ESS on perceptions of competitive performance when viewed from a learning perspective. The model proposes two types of learning: mental-model maintenance, in which new information fits into existing mental models and confirms them; and mental-model building, in which mental models are changed to accommodate new information.

The results of a survey of seventy-three executives support the view that the success of ESS may be contingent upon the type of executive learning they engender. The research found that perceptions of competitive performance resulting from ESS use are strongly related to mental-model building, but found no link between competitive performance and mental-model maintenance. Hence, it seems that ESS can and do foster executive learning. Nevertheless, organizations that embark on ESS development on the basis of promised gains in competitive performance should proceed cautiously.

Acknowledgments: The authors gratefully acknowledge the financial support provided by SUNCOR through the National Centre for Management Research and Development at the Western Business School and by the Social Sciences and Humanities Research Council of Canada.

Journal of Management Information Systems / Fall 1995, Vol. 12, No. 2, pp. 99–130

The presence of analysis capability seems to be the best differentiator between mental-model maintenance and mental-model building, leading to a consideration of behaviour vis-à-vis the ESS as a predictor of learning. Without mental-model building, competitive performance gains seem unlikely. In addition, companies should be leery of systems that are justified on the basis of improved technical quality.

KEY WORDS AND PHRASES: executive support systems, organizational learning.

ADVANCES IN TECHNOLOGY HAVE MADE IT POSSIBLE TO PROVIDE MANAGERS with far more information, in a far more flexible form, than has been true in the past. Recently, some of the effort expended on providing top management with information has been in the development of executive support systems (ESS). These systems are designed to provide executives with high-quality information in a form that is easy to access, and use, and is relevant to decision making [47, 78]. ESS are typically, but not necessarily, used directly by top management and focus on a manager's or group of managers' information needs across a range of areas. Rather than being limited to a single recurring type of decision, they are billed as flexible tools that provide information support and analysis capability for a wide range of executive decision making.

The business press is rife with articles about the successes many organizations have had with their ESS [39]. Even so, executive support systems are far from an unqualified success, and failures have been common (e.g., [67, 107]). Watson [106] comments:

> For most organizations, an ESS is a high-risk application. It serves users who have poor computer skills and are sceptical about whether computers can help improve their job performance.... So a logical question is, is it worth the trouble? [P. 91]

In addition, the investments to create, implement, and maintain ESS are substantial and ongoing [108].

One of the reasons why executives may find their ESS unsatisfactory is that they do not really provide them with information. Davis [25] states that information is "data that have been processed into a form that is meaningful to the recipient and is of real or perceived value in current or prospective decisions" (p. 32). Others define information as data (stimuli and symbols) "conveying meaning as a result of reducing uncertainty" [50]. As Daft and Huber [22] point out, however, some information increases your perception of uncertainty by "alerting you to the presence of conditions you felt certain did not exist" (p. 31). Ungson, Braunstein, and Hall [101] define information as "stimuli (or cues) capable of altering an individual's expectations and evaluation in problem solving or decision making" (p. 117). If one adopts a cognitive perspective on learning, this definition of information implies that data can only be considered information if they are capable of engendering learning in the receiver.

Information and learning are frequently linked. For example, Lovell [62] argues that "all learning . . . implies the reception of new information, its retention over a period of time and its subsequent recall" (p. 22). Huber [51] believes that "*An entity learns* *if, through its processing of information, the range of its potential behaviors is changed*" (p. 89, emphasis in original). Given that ESS are meant to provide executives with valuable information, an appropriate measure of their success may be whether or not they help executives learn.

Although learning has been associated with information technology (e.g., [4, 16, 46, 56]), the links among technology, learning, and competitive performance have not been investigated. This paper considers the effects of ESS use on learning. Specifically, the relationships among ESS characteristics, individual differences, learning, and perceptions of competitive performance are investigated. The next section reviews relevant research and develops the research model. This is followed by a description of the method used to investigate the model. Then the findings are presented. The final section discusses the implications of the findings for research and management, and outlines potential avenues for future research.

Literature Review and Research Model

A FUNDAMENTAL ISSUE FACING RESEARCHERS OF LEARNING IN ORGANIZATIONS is the selection of the level of analysis appropriate to the investigation. One can investigate the phenomenon at either the individual or the organizational level. Proponents of the organization as the appropriate level of analysis believe that organizational learning is not merely aggregated individual learning [5]. While organizations learn through the experiences of individuals [89, 92], they have "memories" that endure beyond the tenure of those individuals [105]. However, the fact remains that organizations can only learn through the individuals within them.

It is particularly worthwhile to focus on senior executives' learning because they have the greatest capacity to affect their organizations' behaviors and, thus, their organizations' willingness to change and learn. Upper-level managers interpret information for the entire organization [23]. They influence their organizations by setting agendas for subordinates' activities consistent with their own personal problem formulations [65]. In addition, executives codify/reify those agendas and problem formulations by establishing and initiating structural and system changes to support them. Consequently, this research focused on individual learning at the executive level.

Literature from four areas was significant to the development of a research model of the relationships among ESS, executive learning and competitive performance. First, the ESS literature provided descriptive case studies that encouraged a learning perspective in ESS effectiveness research. Second, the literature on individual cognitive learning found in educational psychology provided a theory of the way in which people learn. Management literature supported this theory in organizational settings. Finally, research into the effect individual differences and system characteristics have on system success provided a list of attributes likely to affect ESS impact on learning and competitive performance. Each of these areas will be discussed in turn. The section concludes with a description of the research model that emerged from the literature.

Research into ESS

There has been a plethora of practitioner literature about ESS. This literature is largely prescriptive in nature, frequently advising managers how to proceed and how to avoid failure (e.g., [14, 67, 77]. Unfortunately, there is a paucity of academic literature focusing on the ingredients for effective top management information automation [103]. Furthermore, there is even less focusing on the impact that ESS have on executives and their organizations. Hence, there is a shortfall in theory development and verification in the literature as it relates to competitive performance. However, there are indications of learning in some ESS case studies.

The term "executive information support system" was coined by Rockart and Treacy [85]. They investigated sixteen companies in which at least one of the top executives directly accessed and used computer-based information. On the basis of these case studies, Rockart and Treacy argued that ESS held great promise for three principle reasons: (1) through personalized analysis, they could assist top managers with their search for deeper understanding about their organizations and industries; (2) ESS could be flexible enough to accommodate the needs of individual managers; and (3) ESS could start small. They saw ESS as a way of providing executives with a more data-intensive approach to their jobs. While learning was not explicitly addressed in this research, it is implicit in the notion of a search for deeper understanding. Comments from the executives that Rockart and Treacy interviewed provide further evidence of the learning some of them experienced when using their ESS:

> The system has been of infinite help in allowing me to improve my mental model of the company and the industry we're in.
>
> You learn the nature of the real question you should have asked when you muck around in the data.
>
> By working with the data I originally thought I needed, I have been able to zero in on the data I actually need. [P. 86]

In their study of thirty ESS, Rockart and DeLong [83] found only a few examples of ESS that were designed to enhance "one's perspective of the business environment" (p. 131) and noted that mental-model enhancement was rarely cited as a primary motivation for development. Nevertheless, they found evidence that mental models were enhanced in several cases. These cases emphasized the importance of challenging conventional wisdom, recognizing unusual trends, and reflecting on information.

The ESS literature contains a number of single case studies that describe how ESS have been implemented, the benefits that have been derived, and the lessons learned (e.g., [20, 29, 47, 70]). There are clear indications that learning, although not the focus, was a byproduct of some of the systems described in these cases.

The British Airways' ESS, described by Cottrell and Rapley [20], is centered on measuring key performance indicators to meet the company's business goals. There is evidence that the system has resulted in significant learning. For example, the ESS was attributed with providing British Airways with information and analysis in a manner that enabled the organization to react differently than the competition to the

Chernobyl nuclear disaster, resulting in increased market share and profitability as a consequence. Even though learning was not an expressed aim of the system, it appears to have been an outcome.

Mohan, Holstein, and Adams [70] discuss the importance of senior management access to extensive detail in their description of an ESS developed for OGS, a large agency of the New York State government. They state that what is needed in ESS is:

> A *broader sweep* of data, often at an *increased* level of detail, with the ability to access and analyze this data (sic) on an *as-needed* basis. . . . Only by using data that has not already been filtered and processed can the system help in problem finding and opportunity spotting. [Pp. 437–438]

Features of the OGS ESS include the ability to cut through organizational levels and categories to track down problem sources, and extrapolation and trend analysis features. Mohan, Holstein, and Adams believe the system has led to a substantive change in the organization's culture. Once again, although there is no explicit discussion about learning, there is evidence in the case that encourages further investigation into learning as a determinant of ESS success.

El Sherif and El Sawy [29] describe a DSS that was designed to support the entire strategic decision-making process rather than a well-structured phase of a specific decision type. While called a DSS, the system that is described encompasses typical ESS features. This is consistent with Silver's [91] definition of DSS which subsumes ESS under it. In their comparison of conventional and issue-based DSS approaches, El Sherif and El Sawy refer to the importance of balancing "divergent exploration and convergent structuring" (p. 567) and recognize that traditional DSS focus only on the convergent structuring of information. Learning, as defined by cognitive theorists, supports the notion of these two distinct forms of knowledge acquisition.

Individual Learning

Cognitive theorists believe that human minds engage in processing that mediates between environmental stimuli and overt responses. Behavior is not a property of the stimulus, but rather, is something that emerges from the interaction of the stimulus and the active mind and memory of the recipient. For many of them, a change in the potential for behavior, rather than behavior itself, constitutes learning [62]. Others, however, believe that learning requires more than potential. For example, Norman [72] defines learning as "purposeful remembering and skillful performance" (p. 3).

The gap between learning and performance often widens with the complexity of the material to be learned [62]. In organizations, particularly in the case of executives, opportunities to display learning through a change in behavior can be far removed from the acquisition of information that prompted the change. Many variables may have to be manipulated before a change can occur and many factors moderate the ability to behave differently. As such, following Huber [51] and Lovell [62], learning was defined in this research as the potential for change in performance, rather than the behavioral change itself. The cognitive school of learning from which this definition is derived provided the theoretical base from which executive learning was investigated. A more detailed description of the theory and its concepts comes next. In particular, mental models [21] are explained in relation to individual learning.

Mental Models

There are a number of overlapping constructs and terms to disentangle in relationship to cognitive theories of learning. Bartlett [9] proposes that memory is guided by a mental structure he calls a schema, defined as "an active organization of past reactions, or of past experiences, which must always be supposed to be operating in any well-adapted organic response" (p. 201). The active nature of schemata as he defines them implies that they are emergent in nature, and constantly changing and developing in response to experiences [12]. Craik [21] describes the workings of the mind in terms of mental models. He argues that reasoning consists of creating models in the mind that have similar relationships and structures to those of the external processes they imitate. For Tolman [100], learning consists of building representations of the environment that are consulted prior to behavior. He calls these representations cognitive maps.

Brewer [13] sorts out the various terms and the distinctions among them and concludes that the term "mental model" could be used to refer to "all forms of mental representation, general or specific, from any domain, causal, intentional or spatial" (p. 193). "Mental model" seems to be gaining currency in the management literature as well (e.g., [26, 79, 78, 89]). Consequently, and as recommended by Brewer [13] and Johnson-Laird [55], "mental model" is used throughout the remainder of this paper to refer to the mental representations that individuals use to guide reasoning.

The mental-model concept stipulates a number of characteristics about human information processing and knowledge representation. A core premise of the cognitive school and schema theory is that humans come to any task with mental models created out of their prior experience and understanding. These mental models determine how environmental stimuli will be interpreted and incorporated or synthesized, and even whether or not cues will be noticed and used. Mental models also make knowledge and information processing more efficient by making it unnecessary to construct understanding from scratch each time similar stimuli are encountered. They facilitate learning by allowing humans to fill gaps in both information and memory, and to construct updated models of reality [86].

Mental models are considered indispensable to information processing because they organize knowledge in simple, robust, and parsimonious ways, in a world awash with information of staggering complexity [87, 94, 104]. However, there is a tendency for people selectively to perceive environmental cues that confirm their existing mental models [31]. Consequently, misconceptions can persist and accumulate until reality jolts perceivers out of their beliefs [98].

Mental Models and Learning

A cognitive perspective implies a dynamic approach to learning. Learning emerges from the interaction of a stimulus and the mind of the learner, and results in a change to the learner's mental model. Cognitive theorists are fairly consistent in their descriptions of the learning process (e.g., [37, 63, 72, 78]). They typically distinguish between two forms of learning: "mental-model maintenance" and "mental-model building." In mental-model maintenance, existing mental models are appropriate or believed to be appropriate, to a given situation. New information fits into the model and confirms what was already held to be true. Mental-model building refers to the process of changing mental models either to fit with new environments, or to handle disconfirming information.

Mental Models and Management Literature

Theories about mental models in organizations state that, while both maintenance and building are important, maintenance is the more likely behavior [58, 80]. Model maintenance implies that basic routines remain appropriate. In comparison, model building is much riskier and its benefits more remote. New ideas, markets, and products have much longer time horizons, more uncertain outcomes, and more indirect results than the exploitation of existing ideas, markets, and products [64]. Moreover, frameworks and criteria for their evaluation are lacking. Yet, without model building, entropy commences and the organization ultimately fails [44]. Indeed, competitive sustainability requires that organizations both explore the unknown and exploit the known [45].

Managerial examples abound illustrating the way in which an individual's, a company's, or even an industry's "impoverished views of the world" [109] have resulted in suboptimal decision making and action. The American automobile industry's obsolete view of consumers in the late 1960s and early 1970s and its subsequent inability to recognize changing needs and wants had dire consequences [58], the effects of which continue to be seen today. Similarly, Hall's [44] characterization of the downfall of the *Saturday Evening Post* points to a mismatch between managers' perceptions of their competitive environment and the changing nature of the magazine business. Also, Porac, Thomas, and Baden-Fuller [79] argue that shared intraorganizational mental models of competition in the Scottish knitwear industry blinded those suppliers to new forms of competition from Italian knitwear suppliers. In a more recent study, Barr, Stimpert, and Huff [8] illustrated the different ways that mental models can change in response to environmental shifts. They conducted a historical study of two railroads and found two distinctly different modes of mental-model change, corresponding closely to the concepts of mental-model maintenance and mental-model building. In the more successful railroad, senior managers changed their mental models often, whereas in the less successful railroad, changes in mental models were not evident until the organization was near bankruptcy. All these research studies come to similar conclusions about the important relationship between flexible executive mental models and competitive performance.

In summary, mental models direct the gathering and processing of stimuli, and stimuli, in turn, help to enforce or change mental models. However, radical changes in mental models are probably rare. Mental models are typically augmented rather than replaced outright [18]. The relationship between flexible executive mental models and competitive performance has significant implications for executive learning.

Superior competitive performance is likely dependent upon management's ability to learn and make sense of uncertain and ambiguous competitive environments [66, 97]. Hence, ESS should contribute significantly to managers' abilities to read their environments and manage their organizations' competitive performance. The role they play is that of providing stimuli for executives to process. These stimuli may lead to learning in one of two ways. First, they can help to confirm managers' extant mental models. An executive may learn to hold his or her position more strongly as a result of the information provided by an ESS. Second, information contained in an ESS may refute existing mental models, and encourage and facilitate the development of new ones. Managers may learn to think about their businesses in entirely or partially new ways through their processing of the information contained in their ESS. Since model maintenance most likely happens as a matter of course [31, 80], organizations need to ensure that the conditions for learning through mental-model building are present [68]. This seems to imply that ESS are more useful to their organizations when designed such that mental-model building is encouraged.

Antecedents to Learning

MIS researchers have a long history of attempting to determine the factors that are salient to behaviours vis-à-vis system use and effectiveness [41, 113]. MIS researchers also have a long history of criticizing this sort of research because of inconclusive results attributable to a lack of theoretical grounding [57] and methodological flaws [53]. Terborg [96] and Nelson [71] propose that, rather than attempting to find or develop a unifying theory to determine which are the relevant factors to investigate, researchers should select individual and situational factors to study based on the strength of the theoretical and empirical support underlying each.

Since the relationships among antecedent constructs and learning have not been studied previously in the MIS context, the current theories and empirical findings have been extended to learning. This is justifiable because it is self-evident that learning arising from an ESS—or from any system for that matter—cannot take place unless the system is used, at least to some extent. For nonmandatory systems, there is usually a strong relationship between use and success, although the direction of causality is not clear. At the same time, however, one must not presume that relationships among antecedent constructs and use will necessarily carry over to their relationship to learning. Antecedents to learning have been divided into two groups: characteristics of the ESS and individual differences, leading to the research model shown in figure 1.

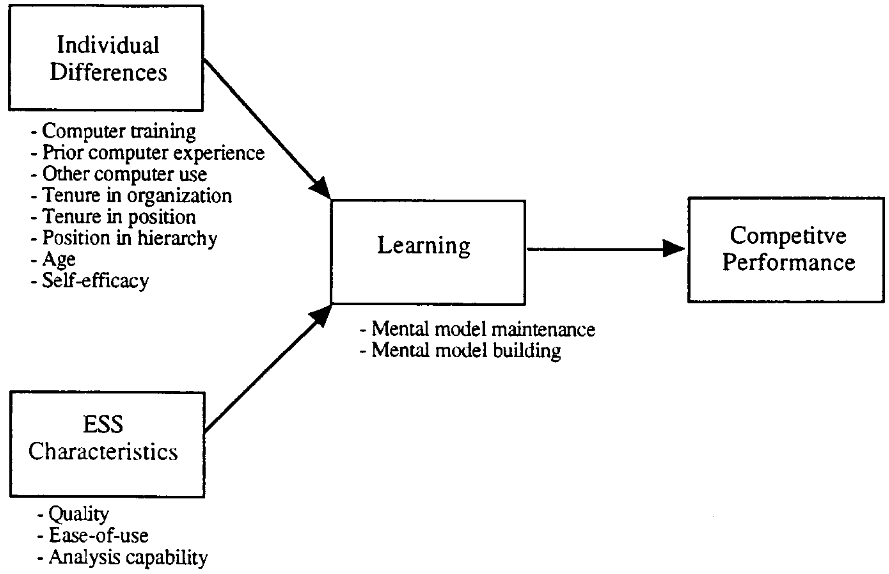

Figure 1.

Research Model

The research model depicts the impact of ESS on perceptions of competitive performance when viewed from a learning perspective. System characteristics and individual differences influence whether mental-model maintenance and/or mental-model building will occur when ESS are used in organizations. Both are believed to be important to perceptions of competitive performance. Mental-model maintenance and its exploitation of the known [64] through logical incrementalism [80] is an important way to enhance competitive performance. Because of its incremental nature, however, the impact of mental-model maintenance on perceptions of competitive performance is expected to be less than the impact of mental-model building. The latter is crucial to forestall systemic entropy and ultimate failure [64]. Hence, model building is necessary if substantial competitive performance improvements are to be realized by organizations.

The specific individual differences and system characteristics that were selected for study are described next.

Individual Differences

Zmud [113] grouped individual differences into cognitive factors, demographics, and personality. Cognitive factors have not been successful in MIS research [2, 49, 73, 74]. Furthermore, no theory exists to support relationships among demographic factors and information retrieval behaviors [110]. Nevertheless, the impact that demographic characteristics have on system success has been studied in several contexts.

In a study of developers of end-user computing, Gallupe [36] found that older users were less successful. He also found that there were no differences among users on the basis of gender or education. In a study of the factors of end-user computing success conducted in ten large organizations, Rivard and Huff [81] found that computer background moderated attitude which, in turn, was positively related to overall satisfaction. Similarly, in a study of 187 end users, Igbaria [52] found that training and computer experience had strong positive effects on attitude and usage. As with computer self-efficacy, it would seem that younger, more computer-literate executives would be more prone to mental-model building behavior.One personality trait, computer self-efficacy, was considered a possible candidate for differentiating between mental-model maintenance and mental-model building. Compeau and Higgins [19] found that computer self-efficacy, "a judgement of one's ability to competently use a computer," was significantly related to outcome expectations and system use in a study of 1,020 end users. Therefore, in the ESS context, it would seem plausible that executives with higher computer self-efficacy would be more comfortable with the functionality of the system and, consequently, would be more able to use the system than individuals with lower computer self-efficacy. However, it is not clear that self-efficacy would differentially impact the two types of learning.

System Characteristics

Quality

Bergeron and Raymond [11] reported that information quality was the most important attribute of ESS. Rockart and DeLong [83] list "data presented in more meaningful formats" as an attribute enabling mental-model enhancement. In addition, quality has often been studied in other IS contexts as a determinant of use or success. For example, Zmud [112] empirically derived several dimensions of information quality. He found that high-quality information was relevant, accurate, factual, complete, reliable, timely, orderly and precise, readable and reasonable. He also found that accurate and timely information contributes to system success. In a study to determine the impact of perceived quality and accessibility on the use of information, O'Reilly [76] operationalized Zmud's definition and found that accuracy, specificity, relevance, reliability, and timeliness were indicative of information quality. He found that perceived quality of information available for decision making was related to the importance ranking of information sources. Swanson [95] found that quality plays a more significant role than accessibility in the selection of an information channel. Doll and Torkzadeh [27] developed an instrument to measure satisfaction that contained several subdimensions relating to quality. Their conceptualization of satisfaction consisted of content, accuracy, ease of use, format, and timeliness. In summary, content, accuracy, format, and timeliness are all components of quality as defined by Zmud [112], O'Reilly [76], and Swanson [95].

Given the strong relationship found between quality and use or success in several different contexts, it would appear that the higher the quality of the system, the greater the possibility that it will promote learning. However, it is unclear how quality would differentially affect mental-model maintenance and mental-model building.

Ease of Use

Perceived ease of use is often a good predictor of system success [24, 27]. Yet, Bergeron and Raymond [11] found that the user interface was a relatively less important ESS attribute. This may be the case because ease of use is a definitional component of ESS [78] and because earlier difficulties with ESS interfaces have been overcome to a large extent [107]. ESS are designed so they are easy for executives to use, particularly those executives with neither the time nor the inclination to learn computer systems. Therefore, it would seem unlikely that ease of use will be a strong predictor of learning via ESS, as it is unlikely to differentiate between users and nonusers of the technology if developers have been successful. However, ease of use is not an objective dimension. It is dependent on the user's experience, expectations, and personal preferences [82]. Hence, whether or not ease of use is a useful construct in this context is an empirical question that needs to be answered.

Analysis Capability

Rockart and DeLong [78] refer to the importance of "analysis capability" for enhancing mental models, and Rockart and Treacy [85] also allude to its importance. Bergeron and Raymond [11] considered analysis capability to be a subset of technical capability, and found that it was less important than other attributes to the success of ESS. In a review of the literature on managerial support systems (defined as information technologies that support managerial activities), Benbasat and Nault [10] found that modeling features improved decision-maker performance. While the evidence is not entirely consistent, it would seem that analysis capability (the ability to perform analyses on the data resident in the ESS) is indeed important to learning, and is more likely to be related to mental-model building.

In summary, demographic factors, computer self-efficacy, the ESS's quality, its ease of use, and its analysis capability are all expected to affect the type of learning that an ESS encourages.

Method

To investigate Figure 1, a mail survey was undertaken. It provided data to study the way in which executives perceive the relationships between mental-model maintenance and perceptions of competitive performance and mental-model building and performance. In addition, it tested whether or not ease of use, quality, analysis capability, demographic characteristics, and self-efficacy affect the type of learning that is possible through ESS.

Construct Operationalization

Tested scales for the model's constructs were used whenever they were available, and were modified only as absolutely necessary to apply to the ESS context. All the items employed either five- or seven-point Likert scales in their original instruments. The differences in validity, methods effect, and residual error are slight between five- and seven-point scales [3]. Hence, all questions were converted to five-point Likert scales regardless of the original operationalization, as consistency within the questionnaire was judged to be more important than consistency with the original scale. Five-point scales were chosen because most of the original scales were operationalized as such.

The model's constructs were perceptual. However, they are just as significant as "hard data" measurements. Indeed, what managers believe is important because perceptions often dictate behaviors [1] (cf. [38]). What follows is a description of each of the scales used. (The appendix contains the survey questions.)

Demographic Factors

Training was operationalized following Igbaria [52]. The questions asked respondents to indicate the amount of computer training they had received from five sources: college or university, hardware or software vendors, consultants, company training programs, and tutorials. The remaining demographic factors—experience, other computer use, tenure in organization and position, organizational level, and age—were operationalized via single questions.

Computer Self-Efficacy

Compeau and Higgins [19] employed a ten-item scale to measure computer self-efficacy. The high reliability of the scale (Cronbach's alpha was 0.94) coupled with the length of the current instrument prompted a pruning back to the five items with the highest factor loadings. Compeau and Higgins's results indicated that these five items were nearly as reliable as the longer scale (Cronbach's alpha was 0.90).

Perceived Ease of Use

Davis's [24] six-item scale for perceived ease of use was included in the questionnaire. He followed a careful process to develop a reliable and valid scale to measure perceived ease of use. In two separate studies, the scale attained exceptionally high reliability scores (Cronbach's alphas were 0.86 and 0.94) and high scores on measures of convergent and discriminant validity.

Quality

O'Reilly [76], Swanson [95], and Zmud et al. [114] have empirically investigated the quality construct. Swanson [95] divided quality into two components: technical quality and information value. He defined technical quality as the objective measures of quality such as reliability, precision, accuracy, timeliness, comprehensiveness and conciseness, and information value as the measures that relate the quality of the information to its specific user (i.e., usefulness, relevance, importance, meaningfulness, value).

No clear list of scale items defining quality emerge from a comparison of the scales of these three researchers. For example, Zmud et al. [114] included dependability as a component of accessibility and reliability as a component of quality, while Swanson [95] considered both part of technical quality, and O'Reilly [76] included only reliability.

O'Reilly's scale was chosen as the basis for the quality construct because of its Likert format (the other two were semantic differential scales) and high reliability (Cronbach's alpha of 0.89). O'Reilly's seven quality items were modified slightly and four additional items were added to incorporate major components of the Swanson and Zmud operationalizations that were absent from the O'Reilly scale. These include suitability, interpretability, helpfulness, and efficiency.

Analysis Capability

Two questions were created to investigate ESS analysis capabilities. The first questioned the ESS's usefulness for analyzing company performance; the second questioned its usefulness for developing new ways to analyze data.

Mental-Model Maintenance

Three questions were developed to tap the concept of mental-model maintenance. They focused on its convergent nature. One question asked about the impact of the ESS on understanding the business, another on the usefulness of the ESS for staying close to the business, and the third, the ESS's usefulness for increasing focus.

Mental-Model Building

The questions to tap the mental-model building construct focused on the divergent nature of the concept. One question asked how useful the ESS was for improving insights and creativity; the other, the ESS's usefulness for testing assumptions about the business.

Competitive Performance

Two questions were asked: one investigating the usefulness of the ESS for keeping up with the competition, and the other, the ESS's usefulness for surpassing the competition.

Pretest Results

The questionnaire was reviewed by colleagues, an executive support system vendor, and a consultant to top management before being pretested by the senior executives at a Canadian resource-based conglomerate. Respondents in the pretest included the chairman of the board, the president and CEO, the CFO, divisional executive vice-presidents, and, at the company's request, the senior external auditor. The company contact was the corporate controller, who ensured that respondents included heavy, moderate, and light users of the system. Individually addressed explanatory letters, surveys, and return envelopes were sent to the contact who agreed to distribute them and ensure that responses would be prompt. The response rate for the pretest was 87.5 percent. Upon completion of the pretest survey, the contact and one other respondent were interviewed in order to determine their reactions to it. Both indicated that they found the survey relevant and straightforward. Based on the positive feedback from the pretest respondents, a survey was undertaken of a cross-section of Canadian companies using executive support systems.

Study Sample

Contacts were made with ESS software vendors and consultants to obtain the names of companies that had an ESS that had been installed for at least three months. In addition, the popular press was scanned for companies with ESS that they might be willing to talk about. This approach ensured that the survey respondents had access to ESS that were considered at least modestly successful by some organizational members, and that they had had access long enough to form opinions about the questions posed in the survey. At this stage of the research, it was felt that understanding the interrelationships among the constructs was more important than generalizability.

In each company, a contact person was interviewed to ensure that the ESS had been in full operation for at least three months, and was available for use by the most senior managers of the organization. Once the system was deemed qualified for inclusion, the survey was administered as in the pretest described above. The contacts were explicitly asked to send questionnaires to all people who had access to the system, whether or not they actually used it, in order to ensure that potential learning style biases for and against ESS use were included among the respondents. All respondents were guaranteed confidentiality. Nonrespondents were contacted once more by the company contact.

Thirty-four companies were contacted about participation in the survey. Of these, three companies had dismantled their systems, six companies did not have a system that met the criteria, six companies declined, and ten companies found the timing inconvenient and asked to be surveyed at a later date. The remaining nine companies, from various industries including natural resources, chemicals, banking, utilities, and industrial products, agreed to participate in the study, for an organizational response rate of 26.5 percent. Three of the companies were Canadian subsidiaries of multinational organizations, three were Canadian multinationals, and three were companies operating across Canada. All of the companies appeared in the *Financial Post* list of the 500 top Canadian companies. Mean sales for 1990 for the nonbanking companies was CDN$ 2.3 billion and the mean number of employees was 5,035. Two of the sample companies were banking institutions. Their mean 1990 total income was

Table 1 Response Rate by Company

Company	Completed surveys	Response rate
1	6	86%
2	5	83%
3	3	60%
4	28	28%
5	11	55%
6	4	57%
7	5	83%
8	4	31%
9	7	70%

CDN$ 5.7 billion and their mean number of employees was 21,408. Eight of the nine ESS had been developed using either Comshare's Commander or Pilot's Command Center. The ninth ESS had been developed in-house.

Discussions with developers indicated the systems that were included in the survey had been designed to provide executives with information that was fundamental to their organizations' competitiveness. For example, one company provided information that enabled their executives to move away from managing transactions, and instead, toward managing a portfolio. Another provided customer service information that was deemed to be a strategic necessity in maintaining market leadership. A third company built an extensive international system that enabled executives to monitor aspects of all major businesses. A fourth tracked early warning indicators of future market trends. In all cases, the systems provided both operating and financial information across a wide range of areas within their respective organizations.

One hundred and seventy-four surveys were distributed; seventy-three were returned, for a response rate of 42 percent. (Table 1 analyses the response rate by company.) The mean age of the respondents was 43 years, and the mean number of layers to the president was 1.96. The presidents of six of the nine companies completed the survey. Thirty percent of the respondents reported to the president. The mean tenure in the company was 16.9 years and the mean tenure in the job was 3.1 years. The mean time the ESS had been available for use was 16.8 months. The respondents had a wide range of system usage varying from no use to four hours per day. The mean daily use was 0.67 hours with a standard deviation of 0.68.

Two analyses were undertaken to ensure that there were no significant company differences in the sample. Because the number of respondents from most of the organizations was less than required for parametric statistics, nonparametric statistics were used in the first analysis. A series of Kruskal-Wallis one-way anovas [90] was undertaken to test if the demographics of the respondents were consistent across companies. No significant differences were found at $p < 0.05$ for tenure in the company, tenure in the position, layers to the president, or age.

A second analysis was undertaken to ensure that company 4 did not skew the sample, given the large proportion of respondents from that organization. First, the sample was split into two subsamples, one containing the company 4 respondents, and the other containing all the others. Pearson correlation co-efficients between the mental-model maintenance, mental-model building, and competitiveness items were calculated for each subsample. In all but one combination, the significance of the correlations was the same between the two subsamples.

Data Analysis

Two analyses were undertaken. In the first, Pearson correlation coefficients between the demographic factors and the two mental-model constructs were calculated (simple averages were calculated for the multi-item scales). Table 2 lists these correlations and their significance.

There were no significant relationships (at $p \leq 0.05$) between the demographic factors and the mental-model constructs. These results are at odds with what was predicted by the results reported in the literature linking use demographics, use, and attitude. Hence, it may not be appropriate to generalize findings relating to other information technologies to the ESS context.

Partial least squares analysis (PLS [61, 111]) was used to test the remainder of the model. PLS is a theory-based approach to conceptualization that has been designed to integrate theory and data, and hence, provides a better platform than traditional multivariate techniques from which to construct and verify theory [32, 33]. In the absence of causal modeling, all that can be inferred from survey data are descriptions and correlations. With causal modeling, there is the potential to infer causation with a limited amount of confidence. Another major strength of causal modeling arises from the fact that theory and data take meaning from each other. Hence, the reliability and validity of the constructs can be verified in light of the theory's nomological network and assessed simultaneously with the estimation of the relationships among the constructs.

Partial least squares is an appropriate technique to use in a theory development situation such as this research [7]. Its purpose is to find the highest prediction accuracy possible. Because of its flexibility, PLS provides a powerful way to understand the interaction between theory and data. In addition, PLS has minimal data assumptions. No specific distributions are required and there are no assumptions about the independence of observations. Finally, small samples work well in PLS. Because PLS is a regression-based technique, it requires at least ten cases for each variable in the most complex multiple regression. (The most complex multiple regression is the dependent construct with the greatest number of paths leading to it.) PLS uses ordinary least squares to minimize the residual variance and estimate case values. Because of its foundations in regression, PLS can make use of many standard statistical significance tests. For example, jackknifing [34] can be used to generate standard errors and t-values.

Table 2 Correlations between Demographic Factors and Mental-Model Constructs

Factor	Model maintenance	Model building
Computer training	0.1821*	0.0451
Prior computer experience	0.1694*	0.0871
Other computer use	–0.0248	–0.1045
Tenure in organization	–0.1097	–0.0706
Tenure in position	–0.0883	–0.0055
Position in hierarchy	0.0103	0.1030
Age	–0.0301	0.0336

* Significant at $p \leq 0.1$.

Partial least squares has been used in a number of studies in various disciplines such as marketing [6], organizational behavior [48], and MIS [43, 81, 99].

Findings

ALTHOUGH THE MEASUREMENT AND STRUCTURAL PARAMETERS ARE ESTIMATED TOGETHER, a PLS model is analyzed and interpreted in two stages: (1) the assessment of the reliability and validity of the measurement model, and (2) the assessment of the structural model. This sequence ensures that the constructs' measures are valid and reliable before one attempts to draw conclusions regarding the relationships among the constructs [7]. Hence, the results of the research are discussed in two parts: the quality of the construct measurement, and the strength of the relationships in the model.

Construct Measurement

Measures of the constructs were assessed by examining individual item reliability, internal consistency or convergent validity, and discriminant validity.

Reliability

As a first step, individual reliabilities for the constructs in the model were assessed. A common rule of thumb for the minimum criteria for acceptance of an item is that it has a loading of greater than 0.7 on its respective construct, implying that more than half of the observed variance of the variable is explained by the construct it measures [15].

The initial factor structure indicated that two of the constructs were problematic. Quality had three items with loadings of less than 0.7. Q2-Timely had a loading of 0.664, Q5-Reliable had a loading of 0.653, and Q6-Accuracy checking had a loading of 0.235. In addition, while it exceeded the 0.7 cutoff, Q1-Accurate had a loading of only 0.714. These results suggested that the quality construct might be multidimensional.

An exploratory principal components analysis with varimax rotation indicated that there were two dimensions to the quality construct that corresponded to Swanson's technical quality and information value. (Table 3 shows the rotated factor matrix.) Given its multidimensionality, the quality construct was divided into technical quality and information value for subsequent analyses. Q6 was excluded from further analysis because of its poor loading on both constructs. This may be due to the fact that Q6 relates to user behavior rather than system characteristics as the remainder of the questions do.

In addition to the problems in the quality scale, one of the items in the self-efficacy scale loaded poorly: S1-No one around to tell me what to do. It was excluded from further analysis.

The PLS model was rerun with the indicated changes to the measurement model. The final factor structure appears in Table 4.

Internal Consistency

The measure of internal consistency developed by Fornell and Larcker [35] was used to assess convergent validity. This measure is similar to Cronbach's alpha, but rather than assuming that each manifest variable contributes equally to the latent variable, it uses the item loadings as they exist in the causal model. Internal consistency of all the constructs was acceptable using Nunnally's [75] guidelines of 0.8 for basic research (Table 5).

Discriminant Validity

Discriminant validity was assessed in two ways. The first test was to ensure that all items loaded more highly on their associated construct than on any other (Table 4). The second test was to compare the square root of the average variance extracted to the correlations between constructs. In all cases, the square root of the average variance extracted was greater than the correlations between constructs. Hence, discriminant validity was acceptable. Table 5 shows the results obtained.

Strength of Relationships

The significance of the path coefficients in the structural model was assessed through a jackknife analysis. The model had high predictive power. It accounted for 30 percent of the variance in competitive performance and 58 and 53 percent of the variance in mental-model maintenance and mental-model building, respectively. Figure 2 shows the path coefficients for the model.

The paths from ease of use, information value, and analysis capability to mental-model maintenance and mental-model building were all substantive and positive, implying that these constructs are related to both kinds of learning. The difference in

Table 3 Rotated Factor Matrix

Item	Factor 1 (information value)	Factor 2 (technical quality)
Q10—Helpful	0.89	
Q9—Specific to needs	0.82	
Q8—Interpretable	0.78	0.35
Q3—Relevant	0.78	0.35
Q4—Meets requirements	0.72	
Q11—Efficient	0.66	0.49
Q7—Suitable	0.61	0.48
Q5—Reliable		0.90
Q1—Accurate	0.31	0.81
Q2—Timely	0.34	0.70
Q6—Accuracy checking		0.39

path strengths for analysis capability (0.10 for maintenance and 0.39 for building) provides a strong indication that this construct distinguishes between maintenance and building, the only one of the antecedent constructs tested that does so.

The path between technical quality and mental-model maintenance was weak. The path between technical quality and mental-model building, at –0.23, was substantive and negative.

The results for self-efficacy were weak. The path between self-efficacy and model maintenance was not substantive. The path between self-efficacy and model building was also weak, but negative. The frequencies for the self-efficacy items were bimodal. Executives had either no confidence or complete confidence that they would be able to use a new function under various conditions. Hence, the self-efficacy measure may not have been psychometrically sound for executives, who may be more definite, self-assured, and confident than people in general. It also may have been inappropriate because the executives are using a technology designed specifically to assuage any anxiety they might have.

The path between mental-model building and perceived competitive performance was substantive at 0.53. At 0.04, the path between mental-model maintenance and perceived competitive performance was not substantive. This finding is somewhat at odds with the research model, which predicted that while building would have a stronger relationship to perceptions of competitive performance than maintenance, both forms of learning would influence it.

Discussion

THE RESULTS OF THE SURVEY IMPROVE OUR UNDERSTANDING of the relationships proposed in the research model. Figure 3 shows the modifications to the model that these results support.

Most important, perceived competitive performance was strongly related to mental-model building, but was unrelated to mental-model maintenance. There are several

Table 4 Final Factor Structure

Item	Ease of use	Technical quality	Information value	Analysis capability	Self-efficacy	Mental-model maintenance	Mental-model building	Comp. performance
E1—Easy to learn	0.827	0.423	0.330	0.222	0.488	0.403	0.239	0.233
E2—Easy to get to work	0.868	0.415	0.518	0.460	0.401	0.463	0.409	0.311
E3—Understandable	0.853	0.373	0.375	0.273	0.496	0.429	0.234	0.167
E4—Flexible	0.730	0.415	0.531	0.444	0.357	0.456	0.490	0.478
E5—Easy to be skillful	0.906	0.514	0.447	0.330	0.539	0.496	0.273	0.202
E6—Easy to use	0.929	0.519	0.471	0.323	0.503	0.511	0.286	0.160
Q1—Accurate	0.167	0.885	0.586	0.250	0.141	0.465	0.242	0.069
Q2—Timely	0.225	0.807	0.584	0.258	0.265	0.460	0.267	0.332
Q5—Reliable	0.177	0.882	0.522	0.232	0.229	0.488	0.133	0.103
Q3—Relevant	0.140	0.585	0.815	0.336	0.264	0.594	0.450	0.279
Q4—Meets requirements	0.273	0.507	0.825	0.511	0.213	0.626	0.529	0.281
Q7—Suitable	0.188	0.508	0.716	0.469	0.266	0.517	0.520	0.353
Q8—Interpretable	0.256	0.543	0.829	0.379	0.233	0.611	0.454	0.187
Q9—Specific to needs	0.358	0.495	0.848	0.538	0.314	0.634	0.572	0.323
Q10—Helpful	0.220	0.609	0.799	0.511	0.129	0.547	0.434	0.303
Q11—Efficient	0.189	0.411	0.701	0.540	0.202	0.560	0.406	0.338
A1—Performance analysis	0.303	0.337	0.565	0.845	0.142	0.479	0.530	0.218
A2—New analyses	0.177	0.127	0.404	0.804	0.218	0.354	0.538	0.385
S2—Written instructions	0.058	0.089	0.204	0.361	0.849	0.208	0.116	–0.009
S3—Seen someone else	0.152	0.236	0.207	0.226	0.773	0.134	–0.011	0.184
S4—Contact available	0.132	0.273	0.192	0.073	0.845	0.258	–0.003	0.143
S5—Lots of time	0.174	0.242	0.328	0.144	0.910	0.394	0.230	–0.100
M1—Understanding business	0.189	0.407	0.564	0.476	0.183	0.768	0.569	0.287
M2—Staying close to business	0.166	0.482	0.702	0.435	0.244	0.902	0.674	0.462
M3—Increasing focus	0.255	0.489	0.580	0.368	0.428	0.834	0.565	0.273

Table 4 Final Factor Structure

Item	Ease of use	Technical quality	Information value	Analysis capability	Self-efficacy	Mental-model maintenance	Mental-model building	Comp. performance
B1—Testing assumptions	0.264	0.174	0.536	0.647	0.078	0.564	0.779	0.486
B2—Insight and creativity	0.204	0.295	0.592	0.542	0.191	0.928	0.915	0.530
C1—Keep up with competition	0.009	0.184	0.364	0.355	0.053	0.405	0.534	0.972
C2—Surpass competition	0.016	0.199	0.347	0.335	0.052	0.392	0.522	0.949

Table 5 Internal Consistency and Correlations between Constructs

	Internal consistency	1	2	3	4	5	6	7	8
1—Ease of use	0.942	0.86							
2—Technical quality	0.894	0.52	0.86						
3—Information value	0.926	0.53	0.66	0.81					
4—Analysis capability	0.810	0.41	0.29	0.59	0.83				
5—Self-efficacy	0.909	0.54	0.25	0.30	0.22	0.85			
6—Model maintenance	0.874	0.54	0.55	0.74	0.51	0.34	0.84		
7—Model building	0.918	0.39	0.25	0.61	0.65	0.14	0.72	0.92	
8—Competitive performance	0.960	0.31	0.20	0.37	0.36	0.05	0.42	0.55	0.96

Diagonal elements are the square roots of the average variance extracted; off-diagonal elements are correlations between constructs.

possible explanations for why there was not a substantive link between mental-model maintenance and perceived competitive performance.

First of all, competitive performance is a complex, multidimensional construct [102]. Perhaps its high-level operationalization in the survey precluded finding a significant relationship between it and mental-model maintenance. For example, mental-model maintenance may impact efficiency but not effectiveness. Second, it

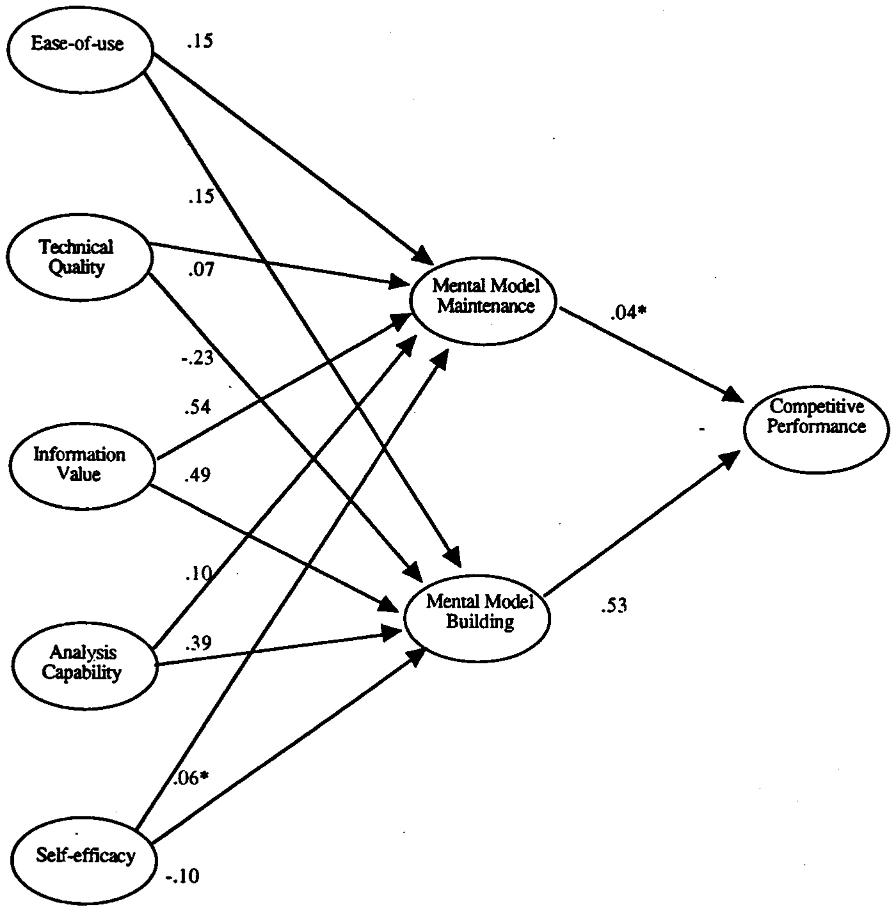

Figure 2.
* Insignificant paths. All other paths significant at $p = 0.05$.

may be that the improvements to competitive performance attributable to the mental-model maintenance resulting from ESS use are too small to measure. Third, executives may use several information channels to maintain their mental models and may not attribute incremental performance improvements to the ESS. Finally, the management literature suggests that mental-model building is critical to long-term competitive performance, while mental-model maintenance is not. The items measuring perceptions of competitive performance may have encouraged the respondents to take a long-term perspective in thinking about competition. Hence, the relationships that were uncovered provide more support for the relationship between mental-model building and perceived competitive performance.

The survey also deepened our understanding of which factors affect mental-model building and mental-model maintenance. Ease of use and information value were both strong predictors of model maintenance and model building, but did not help to distinguish between the two. It would seem that these constructs are necessary but not sufficient conditions for mental-model building and related improvements in competitive performance. It would also seem that ease of use is not yet so common that it does not help to differentiate among ESS.

The weak relationship between technical quality and mental-model maintenance and the negative relationship between it and mental-model building indicate that accuracy, timeliness, and reliability are not only not important, but that an excessive focus on them may limit the potential of ESS to support mental-model building. This is not to say that accuracy, timeliness, and reliability are not important *ceterus paribus*, but rather that in situations where resources are constrained, executives are more interested in new and unusual information. This explanation fits well with the prevailing wisdom of what is important to them [28, 30, 69]. It also fits with Gorry and Scott Morton's [42] admonition that quality decisions are not necessarily improved through improvements in information inputs. Comments made by two of the executives who were surveyed also support this point of view. One executive wrote:

> As a VP, I do not need up to the minute data. . . . I find most of my time is spent figuring out the future, not looking at the past.

Another said:

> Ready access to yesterday's data is unimportant.

While there is little question that many executives need accurate, reliable, and timely information to make some of their decisions, these characteristics may be less important for many of the decisions executives make using the information available in their ESS.

The negative relationship between technical quality and mental-model building requires further discussion, however. It seems unlikely that the lower the technical quality of a system, the more useful it is for mental-model building. Recall that technical quality consists of accuracy, timeliness, and reliability. It may be that too much attention to these items results in an ESS containing information that was already available to executives in other forms, thereby fitting into existing mental models, and precludes information that is different, unusual, and possibly risky: the characteristics it requires for mental-model building. For example, it may be easy for a development team to provide access to balance sheet and income statement information after the month close, although executives have little use for the information since it is retrospective. It may be much more useful for them to look at competitive actions. Unfortunately, developers may have a much more difficult time providing this sort of information.

Analysis capability is the construct that most clearly distinguished between mental-model maintenance and mental-model building. Since the questions relating to analysis capability were worded to ask whether the system was useful for analysis, which is a behavior of the users of the systems, rather than whether it had analysis capability, which is a feature of the system, these results indicate that the type of learning that ESS support may depend, at least in part, on the way they are used. However, it is

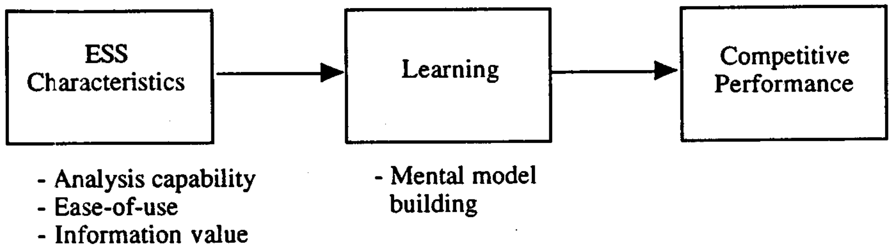

Figure 3.

important to reflect upon what analysis capability means in the ESS context.

Few executives undertake analyses such as developing scenarios and creating percentage comparisons of various operations. They typically have analysts who support them in these activities. The ESS analysis capabilities that most executives avail themselves of are: determining which data will be seen together and hence, which will be compared; selecting presentation formats; manipulating the rows, columns, and sort order of reports; and "mucking around in the data," calculating single ratios or differences depending on what strikes them as important when they see the numbers. The results indicate that these "back of the envelope" analysis capabilities may be more important to mental-model building than to mental-model maintenance. This finding supports Rockart and DeLong [83], who found that "improved analytic and modelling capabilities" (p. 135) are one of the key ESS attributes required for mental-model enhancement.

The research is not without limitations. The first relates to organization bias. It seems likely that organizations that are unhappy with their systems would be less inclined to participate in research of this nature. Hence, the sample of ESS probably contains a larger proportion of "good" systems than is the case in the population of all ESS. A second limitation relates to the notion of causality. While evidence of causality was provided, causality itself was not proven. A third limitation is that of common method variance and same source bias. The research relied on user perceptions and a single method to elicit those perceptions.

Several avenues for future research emerge from this study. First, the strong relationship found between mental-model building and perceived competitive performance should encourage the development of a deeper understanding of what it takes to develop systems that stimulate mental-model building. This research investigated several possible contributing factors, but undoubtedly, more theoretical development in this area will provide factors that may unlock this important cognitive process. For example, future research should investigate the nature of analysis capability and how ESS can be designed to provide the support that executives need to build mental models. Given the difference in the effect of the two mental-model constructs, understanding which factors differentiate between them is fundamental to furthering our understanding of how ESS support improvements in competitive performance. Furthermore, the kind of learning executives engage in because of their ESS may depend on the use to which they put the system. Hence, a consideration of other behaviors that might impact learning may provide insight into the factors that are likely to promote desired outcomes. In addition, more work is required to determine the components of context that are important to mental-model building and whether or not and how they interact with system characteristics.

In addition to improving our understanding of ESS and mental models, the concept of competitive performance should be operationalized at a lower level of abstraction. There is general agreement that performance is a multidimensional construct [102], although there is some disagreement about what the dimensions ought to be. Since it is unlikely that mental-model maintenance has no organizational benefits, research should be undertaken to determine the kinds of impact that the different types of learning have on different aspects of competitive performance such as efficiency, effectiveness, innovation, and consensus building.

Both quantitative and qualitative research will be required to deepen our understanding of the relationships among ESS, individual predispositions, organizational context, learning, and competitive performance. Case studies will help to elucidate how ESS are expected to affect learning and competitive performance and the conditions that are expected to affect how ESS are used; in other words, they will facilitate a description of why ESS are used the way they are and the consequences of that use. Case studies will also assist in more precise operationalization of key constructs. It is important to ensure that the behaviors the constructs describe do, in fact, take place in organizational settings, and that the list of behaviors is complete and measurable. Further survey research that has been informed by qualitative studies will enable both triangulation and statistical analysis of the findings across a much wider variety of settings than is possible in qualitative research.

Conclusion

THIS STUDY DEVELOPED AND TESTED A PRELIMINARY MODEL OF THE RELATIONSHIPS among ESS, learning, and performance. In accomplishing this objective, the research made contributions to the fields of MIS and organizational learning and has several implications for managers.

First, the research provided insight into whether or not and how ESS contribute to learning and competitive performance in organizations. It seems that ESS can contribute to both forms of learning: mental-model building and mental-model maintenance. It also seems that ESS are perceived to contribute more to competitive performance when they enable mental-model building than when they enable mental-model maintenance. Finally, the differences in the relationships between the antecedent constructs and mental-model maintenance and mental-model building contribute to our understanding of how these different forms of learning are encouraged. The research indicates that one way ESS enable mental-model building is through the provision of analysis capability.

Second, the research made a contribution to the field of organizational learning by operationalizing mental-model maintenance and mental-model building and demonstrating that they can be conceptualized as two distinct constructs, at least in this context. Clearly, more research is required to establish their robustness.

The research also has implications for managers. The most important of these relates to the relationship between mental-model building and competitive performance. Organizations that embark on ESS development based on promised gains in competitive performance should proceed cautiously. Without mental-model building, competitive performance gains seem unlikely. Consequently, the inclusion of analysis capability seems crucial to ensure that the ESS will have an impact on competitive performance. In addition, the research points to the fact that if trade-offs must be made between information value and technical quality, information value is the more important. Providing executives with analysis capability to look at new and unusual information should take precedence over providing more accurate, timely, and reliable versions of currently available information. Companies should be leery of ESS that are justified on the basis of improved technical quality. They may find that the systems do very little in terms of organizational performance. Finally, the research indicates that developers must continue their efforts to make ESS easy for executives to use.

The diversity of organizations and ESS that were studied, the large number of executives that participated, and the strength of the results provide compelling evidence to support the research model. ESS can and do foster executive learning and impact competitive performance as a result.

Microcomputer, networking, and database technologies have advanced to the point where an integrated, easy-to-use, and powerful ESS can be built. However, what has distinguished the successes from the failures has not been clear. The research described here supports the view that the success of these systems is contingent upon whether or not they enable executive learning. It may be that learning, rather than the traditional metrics such as ease of use, technical quality, and use, is the most appropriate way to measure their impact.

REFERENCES

1. Ajzen, I., and Fishbein, M. *Understanding Attitudes and Predicting Social Behavior*. Englewood Cliffs, NJ: Prentice-Hall, 1980.

2. Alavi, M., and Joachimsthaler, E.A. Revisting DSS implementation research: a meta-analysis of the literature and suggestions for researchers. *MIS Quarterly* (March 1992), 95–112.

3. Andrews, F. The construct validity and error components of survey measures: estimates from a structural modeling approach. Working Paper Series no. 8031, University of Michigan, 1982.

4. Argyris, C. Organizational learning and management information systems. *Accounting, Organizations and Society*, *2*, 2 (1977), 113–123.

5. Argyris C., and Schön, D.A. *Organizational Leaning: A Theory of Action Perspective*. Reading, MA: Addison-Wesley, 1978.

6. Barclay, D. The impact of the organization context on conflict in organizational buying: a systems view. Unpublished doctoral dissertation, University of Michigan, Ann Arbor, 1986.

7. Barclay, D.; Higgins, C.; and Thompson, R. The partial least squares (PLS) approach to causal modeling: personal computer adoption and use as an illustration. *Technology Studies: Special Issue on Research Methodology*, forthcoming, 1994.

8. Barr, P.S.; Stimpert, J.L.; and Huff, A.S. Cognitive change, strategic action, and organizational renewal. *Strategic Management Journal*, *13* (1992), 15–36.

9. Bartlett, F.C. *Remembering: A Study in Experimental and Social Psychology*. London: Cambridge University Press, 1932.

10. Benbasat, I., and Nault, B.R. An evaluation of empirical research in managerial support systems. *Decision Support Systems, 6* (1990), 203–226.

11. Bergeron, F., and Raymond, L. Evaluation of EIS from a managerial perspective. *Journal of Information Systems, 2* (1992), 45–60.

12. Boland, R.J., and Greenberg, R.H. Method and metaphor in organizational analysis. *Accounting, Management & Information Technology, 2*, 2 (1992), 117–141.

13. Brewer, W.F. Schemas versus mental models in human memory. In P. Morris (ed.), *Modelling Cognition*. New York: John Wiley, 1987.

14. Burkan, W.C. *Executive Information Systems: From Proposal through Implementation*. New York: Van Nostrand Reinhold, 1991.

15. Carmines, E.G., and Zeller, R.A. *Reliability and Validity Assessment*. Sage University Paper Series on Quantitative Applications in the Social Sciences. No. 07–017. Beverly Hills, CA: Sage Publications, 1979.

16. Chorba, R.W., and New, J.L. Information support for decision-maker learning in a competitive environment: an experimental study. *Decision Sciences, 11* (1980), 603–615.

17. Cohen, W.M., and Levinthal, D.A. New perspective on learning and innovation. *Administrative Science Quarterly, 35* (1990), 128–152.

18. Collins, A., and Gentner, D. How people construct mental models. In B. Holland and N. Quinn (eds.), *Cultural Models in Language and Thought*. Cambridge: Cambridge University Press, 1987.

19. Compeau, D.R., and Higgins, C.A. A social cognitive theory perspective on individual reactions to computing technology. *Proceedings of the Twelfth International Conference on Information Systems*, 1991, pp. 187–198.

20. Cottrell, N., and Rapley, K. Factors critical to the success of executive information systems in British Airways. *European Journal of Information Systems, 1*, 1 (1991), 65–71.

21. Craik, K. *The Nature of Explanation*. Cambridge: Cambridge University Press, 1943.

22. Daft, R.L., and Huber, G.P. How organizations learn: a communication framework. In S. Bacharach & N. DiTomaso (eds.), *Research in the Sociology of Organizations*, vol. 5. Greenwich, CT: JAI Press, 1987, pp. 1–36.

23. Daft, R.L., and Weick, K.E. Toward a model of organizations as interpretation systems. *Academy of Management Review, 9*, 2 (1984), 284–295.

24. Davis, F.D. Perceived usefulness, perceived ease of use, and user acceptance of information technology. *MIS Quarterly, 13*, 3 (1989), 319–339.

25. Davis, G.B. *Management Information Systems: Conceptual Foundations, Structure and Development*. New York: McGraw-Hill, 1974.

26. De Geus, A.P. Planning as learning. *Harvard Business Review* (March–April 1988), 70–74.

27. Doll, W.J., and Torkzadeh, G. The measurement of end-user computing satisfaction, *MIS Quarterly* (June 1988), 258–274.

28. El Sawy, O.A. Personal information systems for strategic scanning in turbulent environments: can the CEO go on-line? *MIS Quarterly* (March 1985), 53–60.

29. El Sherif, H., and El Sawy, O.A. Issue-based decision support systems for the Egyptian cabinet. *MIS Quarterly* (December 1988), 551–569.

30. Etzioni, A. Humble decision making. *Harvard Business Review* (July–August 1989), 122–126.

31. Festinger, L. *A Cognitive Theory of Dissonance*. Evanston, IL: Row Petersen, 1957.

32. Fornell C. *A Second Generation of Multivariate Analysis. Methods*, vol. 1. New York: Praeger, 1982.

33. Fornell, C. A second generation of multivariate analysis. Classification of methods and implications for marketing research. Working Paper, University of Michigan, April 1984.

34. Fornell, C., and Barclay, D. Jackknifing: a supplement to Lohmoller's LVPLS program. Unpublished paper, Graduate School of Business Administration, University of Michigan, Ann Arbor, 1983.

35. Fornell C., and Larcker, D. Evaluating structural equation models with unobservable variables and measurement error. *Journal of Marketing Research, 18* (1981), 39–50.

36. Gallupe, R.B. End user computing: individual differences and successful end users. *ASAC Conference, Montreal, 10*, 4 (1989), 61–76.

37. Gagne, R.M. *The Conditions of Learning*. New York: Holt Rinehart and Winston, 1977.

38. Geringer, J.M., and Hebert, L. Measuring performance of international joint ventures. *Journal of International Business Studies* (second quarter 1991), 249–263.

39. Gillan, C., and McPherson, K. White paper: executive information systems. *Computerworld* (October 19, 1992).

40. Gioia, D.A., and Manz, C.C. Linking cognition and behavior: a script processing interpretation of vicarious learning. *Academy of Management Review, 10*, 3 (1985), 527–539.

41. Goodhue, D. IS attitudes: toward theoretical and definition clarity. *Data Base* (Fall–Winter 1988), 181–194.

42. Gorry, G.A., and Scott Morton, M.S. A framework for management information systems. *Sloan Management Review* (Fall 1971), 55–70.

43. Grant, R. Building and testing a model of an information technology's impact. *Proceedings of the Tenth International Conference on Information Systems*, Boston, December 1989, pp. 173–184.

44. Hall, R.I. The natural logic of management policy making: its implications for the survival of an organization. *Management Science, 30*, 8 (1984), 905–927.

45. Hedberg, B., and Jonsson, S. Designing semi-confusing information systems for organizations in changing environments. *Accounting, Organizations and Society, 3*, 1 (1978), 47–64.

46. Henderson, J.C., and Martinko, M.J. Cognitive learning theory and the design of decision support systems. *DSS–81 Transactions*, Atlanta 1981, pp. 45–50.

47. Houdeshel, G., and Watson, H.J. The management information and decision support (MIDS) system at Lockheed-Georgia. *MIS Quarterly, 11*, 1 (1987), 127–140.

48. Howell, J.M., and Higgins, C.A. Champions of technological innovation. *Administrative Science Quarterly, 35*, 2 (1990), 317–341.

49. Huber, G.P. Cognitive style as a basis for MIS and DSS designs: much ado about nothing? *Management Science*, *29*, 5 (1983), 567–579.

50. Huber, G.P. A theory of the effects of advanced information technologies on organizational design, intelligence and decision making. *Academy of Management Review, 15*, 1 (1990), 47–71.

51. Huber, G.P. Organizational learning: the contributing processes and the literatures. *Organization Science, 2*, 1 (1991), 88–115.

52. Igbaria, M. End-user computing effectiveness: a structural equation model. *OMEGA, 18*, 6 (1990), 637–652.

53. Ives. B., and Olson, M.H. User involvement and MIS success: a review of research. *Management Science, 30*, 5 (1984), 586–603.

54. Johnson-Laird, P.N. *Mental Models*. Cambridge, MA: Harvard University Press, 1983.

55. Johnson-Laird, P.N. Mental models. In M.I. Posner (ed.), *Foundations of Cognitive Science*. Cambridge, MA: MIT Press, 1989.

56. Keen P.G. Value analysis: justifying decision support systems. *MIS Quarterly, 5*, 1 (1981), 48–65.

57. Keen, P.G. MIS research: reference disciplines and a cumulative tradition. *Proceedings of the First International Conference on Information Systems*, 1981, pp. 9–18.

58. Kiesler, S., and Sproull, L. Managerial response to changing environments: perspectives on problem sensing from social cognition. *Administrative Science Quarterly, 27* (1982), 548–570.

59. Leahey, T.H., and Harris, R.J. *Human Learning*. Englewood Cliffs, NJ: Prentice-Hall, 1989

60. Levenhagen, M.J., and Thomas, H. Entrepreneurship, cognition, and framing complex environments: evidence from computer-software start-ups. In H. Klandt (ed.), *Recent Research in Entrepreneurship*. Aldershot, UK: Avery of Ashgate, 1992.

61. Lohmoller, J.B. LVPLS 1.6 program manual: latent variables path analysis with partial least-squares estimation. Munich: University of the Federal Armed Forces, 1981.

62. Lovell, R.B. *Adult Learning*. New York: John Wiley, 1980.

63. Maier, N.R.F. Reasoning in humans: III. The mechanisms of equivalent stimuli and of reasoning. *Journal of Experimental Psychology, 35* (1945), 349–360.

64. March, J.G. Exploration and exploitation in organizational learning. *Organization Science, 2*, 1 (1991), 71–87.
65. March, J.G., and Simon, H.A. *Organizations*. New York: John Wiley, 1958.
66. McCaskey, M.B. *The Executive Challenge: Managing Change and Ambiguity*. Marshfield, MA: Pitman, 1982.
67. McAuliffe, T.P., and Shamlin, C.S. *Critical Information Network: The Next Generation of Executive Information Systems*. Wilmington, MA: ZBR Publications, 1992.
68. Miller, D. The architecture of simplicity. *Academy of Management Review, 18*, 1 (1993), 116–138.
69. Mintzberg, H. *The Nature of Managerial Work*. New York: Harper and Row, 1973.
70. Mohan, L.; Holstein, W.K.; and Adams, R.B. EIS: it can work in the public sector. *MIS Quarterly* (December 1990), 434–448.
71. Nelson, D.L. Individual adjustment to information-driven technologies: a critical review. *MIS Quarterly* (March 1990), 79–98.
72. Norman, D.A. *Learning and Memory*. San Francisco: W.H. Freeman, 1982.
73. Nutt, P. Decision style and strategic decisions of top executives. *Technological Forecasting and Social Change, 30* (1986), 39–62.
74. Nutt, P. Evaluating MIS design principles. *MIS Quarterly* (June 1986), 139–155.
75. Nunnally, J.C. *Psychometric Theory*, 2d ed. New York: McGraw-Hill, 1978.
76. O'Reilly, C.A. Variations in decision makers' use of information sources: the impact of quality and accessibility of information. *Academy of Management Journal, 25*, 4 (1982), 756–771.
77. Paller, A. *The EIS Book: Information Systems for Top Managers*. Homewood, IL: Dow Jones-Irwin, 1990.
78. Piaget, J. *The Construction of Reality in the Child*, New York: Basic Books, 1954.
79. Porac, J.F.; Thomas, H.; and Baden-Fuller, C. Competitive groups as cognitive communities: the case of the Scottish knitwear manufacturers. *Journal of Management Studies, 26*, 4 (1989), 397–416.
80. Quinn, J.B. *Strategies for Change: Logical Incrementalism*. Homewood, IL: Irwin, 1980.
81. Rivard, S., and Huff, S.L. Factors of success for end-user computing. *Communications of the ACM, 31*, 5 (1988), 552–561.
82. Robey, D. User attitudes and management information system use. *Academy of Management Journal, 22*, 3 (1979), 527–538.
83. Rockart, J.F., and DeLong, D.W. *Executive Support Systems: The Emergence of Top Management Computer Use*. Homewood, IL: Dow Jones-Irwin, 1988.
84. Rockart, J.F., and DeLong, D.W. Moments of executive enlightenment. *Information Strategy: The Executive's Journal* (1988).
85. Rockart, J.F., and Treacy, M.E. The CEO goes on-line. *Harvard Business Review* (January–February 1982), 82–88.
86. Rumelhart, D.E. Schemata: the building blocks of cognition. In R. Spiro, B.C. Bruce, and W.F. Brewer (eds.), *Theoretical Issues in Reading Comprehension*. Hillsdale, NJ: Lawrence Erlbaum, 1980.
87. Schwenk, C.R. The cognitive perspective on strategic decision making. *Journal of Management Studies, 25*, 1 (1988), 41–55.
88. Schwenk, C.R. Linking cognitive, organizational and political factors in explaining strategic change. *Journal of Management Studies, 26*, 2 (1989), 177–187.
89. Senge, P. M. The leader's new work: building learning organizations. *Sloan Management Review* (Fall 1990), 7–23.
90. Siegel, S., and John Castellan, Jr., N. *Nonparametric Statistics for the Behavioral Sciences*. New York: McGraw-Hill, 1988.
91. Silver, M.S. *Systems that Support Decision Makers: Description and Analysis*, New York: John Wiley, 1991.
92. Simon, H.A. Bounded rationality and organizational learning. *Organization Science, 2*, 1 (1991), 125–134.
93. Sims H.P., and Gioia, D.A. *The Thinking Organization*. San Francisco: Jossey-Bass, 1986.
94. Stubbart, C.I. Managerial cognition: a missing link in strategic management research. *Journal of Management Studies, 26*, 4 (1989), 325–347.

95. Swanson, E.B. Information channel disposition and use. *Decision Sciences, 18* (1987), 131–145.
96. Terborg, J.R. Interactional psychology and research on human behavior in organizations. *Academy of Management Review, 6*, 4 (1981), 569–576.
97. Thomas, H. Policy dialogue in strategic planning: talking our way through ambiguity and change. In L.R. Pondy, R.J. Boland, Jr., and H. Thomas (eds.), *Managing Ambiguity and Change*. Chichester: John Wiley, 1988.
98. Thomas, J.B., and McDaniel, R.R. Interpreting strategic issues: effects of strategy and the information-processing structure of top management teams. *Academy of Management Journal, 33*, 2 (1990), 286–306.
99. Thompson, R.L.; Higgins, C.A.; and Howell, J.M. Personal computing: toward a conceptual model of utilization. *MIS Quarterly, 15*, 1 (1991), 125–143.
100. Tolman, E.C. Cognitive maps in rats and men. *Psychological Review, 55* (1948), 189–208.
101. Ungson, G.R.; Braunstein, D.N.; and Hall, P.D. Managerial information processing: a research review. *Administrative Science Quarterly, 26* (1981), 116–134.
102. Venkatraman, N., and Ramanujam, V. Measurement of business economic performance: an examination of method convergence. *Journal of Management, 13*, 1 (1987), 109–122.
103. Walls, J.G.; Widmeyer, G.R.; and El Sawy, O.A. Building and information system design theory for vigilant EIS. *Information Systems Research, 3*, 1 (1992), 36–59.
104. Walsh, J.P. Selectivity and selective perception: an investigation of managers' belief structures and information processing. *Academy of Management Journal, 31*, 4 (1988), 873–896.
105. Walsh, J.P., and Ungson, G.R. Organizational memory. *Academy of Management Review, 16*, 1 (1991), 57–91.
106. Watson, H.J. Avoiding hidden EIS pitfalls. *Computerworld, 24*, 26 (1990), 87–91.
107. Watson, H.J., and Glover, H. Common and avoidable causes of EIS failure. *Computerworld, 23*, 49 (1989), 90–91.
108. Watson, H.J.; Rainer, Jr., R.K.; and Koh, C.E. Executive information systems: a framework for development and a survey of current practices. *MIS Quarterly, 15*, 1 (March 1991), 13–30.
109. Weick, K.E. Cognitive processes in organizations. In B.M. Staw (ed.), *Research In Organizational Behavior*, vol. 1. Greenwich, CT: JAI Press, 1979, pp. 41–74.
110. Weill, P., and Olson, M. An assessment of the contingency theory of management information systems. *Journal of Management Information Systems, 6*, 1 (1989), 59–85.
111. Wold, H. Systems analysis by partial least squares. In P. Nijkamp, H. Leitner, and N. Wrigley (eds.), *Measuring the Unmeasurable*. Boston: Martinus Nijhoff, 1985.
112. Zmud, R.W. An empirical investigation of the dimensionality of the concept of information. *Decision Sciences, 9* (1978), 187–195.
113. Zmud, R.W. Individual differences and MIS success: a review of the empirical literature. *Management Science, 25*, 10 (1979), 966–979.
114. Zmud, R.W.; Lind, M.R.; and Young, F.W. An attribute space for organizational communication channels. *Information Systems Research, 1*, 4 (1990), 440–457.

APPENDIX: Survey Questions

Training

Please indicate how much computer training you have received from each of the following sources. (College or university, hardware or software vendor, consultant, company training program, self-training [e.g., tutorials]).

Self-Efficacy

I could use the new function . . .

	Not at all confident		Neu-tral		Totally confident
S1—If there was no one around to tell me what to do.	1	2	3	4	5
S2—If I had only written instructions to refer to.					
S3—If I had seen someone else using it before trying it myself.					
S4—If I could contact someone for help if I got stuck.					
S5—If I had a lot of time to complete the task for which the function was provided.					

Quality

	Not at all accurate				Very accurate
Q1—How accurate is the information you get from your company's ESS?	1	2	3	4	5

The remaining questions were asked in the same way with the scales adjusted to fit with the specific content of each (that is, not at all . . . /very . . .).

Q2—How timely is the information you get from your company's ESS?
Q3—How relevant to you, on average, is the information you get from your company's ESS?
Q4—How often is the information you get from your company's ESS exactly what you require?
Q5—How reliable is the information you get from your company's ESS?
Q6—How often do you check the accuracy of the information you get from your company's ESS?
Q7—How suitable is your company's ESS for meeting your typical information needs?
Q8—How easy is it for you to interpret information from your company's ESS?
Q9—How specific to your particular needs is the information from your company's ESS?
Q10—How helpful to you is your company's ESS for supporting your typical decisions?
Q11—In terms of time and effort required to obtain information in comparison

to its value in supporting decision making, how efficient do you find you company's ESS?

Ease of Use

	Strongly disagree		Neu-tral		Strongly agree
E1—The ESS has been easy for me to learn.	1	2	3	4	5
E2—I find it easy to get the ESS to do what I want it to do.					
E3—The method of interacting with the ESS is clear and understandable.					
E4—I find the ESS flexible to work with.					
E5—It is easy for me to become skillful at using the ESS.					
E6—Overall, I find the ESS easy to use.					

Analytic Capability

A1—Usefulness of ESS for analyzing company performance.
A2—Usefulness of ESS for developing new ways to analyze data.

Mental-Model Maintenance

M1—Impact of ESS on understanding of the business.
M2—Usefulness of ESS for staying close to the business.
M3—Usefulness of ESS for increasing focus.

Mental-Model Building

B1—Usefulness of ESS for testing assumptions about the business.
B2—Usefulness of ESS for improving insights and creativity.

Competitive Performance

C1—Usefulness of ESS for keeping up with the competition.
C2—Usefulness of ESS for surpassing the competition.