Building an Information System Design Theory for Vigilant EIS

Joseph G. Walls
Department of Decision Systems
School of Business Administration
University of Southern California
Los Angeles, California 90089-1421

George R. Widmeyer
Department of Decision Systems
School of Business Administration
University of Southern California
Los Angeles, California 90089-1421

Omar A. El Sawy
Department of Decision Systems
School of Business Administration
University of Southern California
Los Angeles, California 90089-1421

This paper defines an information system design theory (ISDT) to be a prescriptive theory which integrates normative and descriptive theories into design paths intended to produce more effective information systems. The nature of ISDTs is articulated using Dubin's concept of theory building and Simons's idea of a science of the artificial. An example of an ISDT is presented in the context of Executive Information Systems (EIS). Despite the increasing awareness of the potential of EIS for enhancing executive strategic decision-making effectiveness, there exists little theoretical work which directly guides EIS design. We contend that the underlying theoretical basis of EIS can be addressed through a design theory of vigilant information systems. Vigilance denotes the ability of an information system to help an executive remain alertly watchful for weak signals and discontinuities in the organizational environment relevant to emerging strategic threats and opportunities. Research on managerial information scanning and emerging issue tracking as well as theories of open loop control are synthesized to generate vigilant information system design theory propositions. Transformation of the propositions into testable empirical hypotheses is discussed.

1. The Need for Information System Design Theories

   The professional schools will re-assert their responsibilities just to the degree that they can discover a science of design: a body of intellectually tough, analytic, partly formalizable, partly empirical teachable doctrine about the design process . . . (Simons 1981)

   Design is “[(the) use of scientific principles, technical information and imagination in the definition of a structure, machine or system to perform pre-specified functions with the maximum economy and efficiency” (Fiedler 1975). Design is central to such varied fields as engineering, architecture, and art. It is also clearly an important topic within the information systems (IS) discipline. Much of our research deals with design-related issues and many of the courses we teach focus on design (Wetherbe 1984; Whitten et al. 1986). IS practitioners are involved in design, as are IS users. That we as a discipline are not more concerned about design theory is surprising given that theory development is one of our major pursuits as academic researchers.

   The IS discipline needs to articulate and develop a class of “design theories.” A design theory is a prescriptive theory based on theoretical underpinnings which says how a design process can be carried out in a way which is both effective and feasible. Since they are prescriptive, design theories differ from explanatory and predictive theories found in the natural or physical sciences. Given that Simons (1981) has long advocated the development of a “science of the artificial,” the idea of design theories is not new. However, little has been done to follow up on Simons’s recommendations. Since Keen’s influential paper (Keen 1980), the conventional wisdom has been that our discipline should draw upon paradigms from other disciplines (Ives et al. 1980). Although we support this as a fruitful strategy, we also believe that our field has not matured to the point where there is a need for theory development based on paradigms endemic to the area itself.

   Our interest in design theories arises from an interest in Executive Information Systems (EIS). Despite increasing awareness that EIS have great potential for enhancing the effectiveness of executive strategic decision-making, there is little theoretical work that directly guides either EIS design requirements or the EIS design process. We argue that the underlying theoretical basis of EIS can be addressed through a design theory of Vigilant Information Systems (VIS), where vigilance refers to the ability of an information system to help the executive remain alertly watchful for weak signals and discontinuities in the organizational environment symptomatic of emerging strategic threats and opportunities. (Our purpose in introducing the acronym VIS is convenience of reference—not to contribute to the proliferation of acronyms in our discipline.)

   Types of information systems for enhancing management support have included management information systems (MIS), decision support systems (DSS), and more recently executive information systems (EIS). MIS anchor on internally-focused variance reporting and are based on theories of control accounting. DSS support the construction of decision models and the use of sensitivity analysis and draw on theories of decision-making and choice. However, the research community knows much less about the core concepts of EIS and their underlying theoretical foundations. There is some agreement that the core concept characterizing EIS is the ability to enhance the effectiveness of top executives in identifying and diagnosing strategic problems and opportunities; however, the theoretical bases by which EIS capabilities relate to the initiation of strategic decision-making and their theoretical links to EIS design guidelines are not well understood.

   Good understanding of EIS design and use is still in an emerging state both in practice and in academia. It is only quite recently that information technology platforms and application generators for EIS have become commercially available. The few vendors who provide these tools present EIS as mainly status monitoring systems that answer “what is?” questions for executives. Typical capabilities of EIS generators
include exception reporting, on-line access to external information utilities, menu-driven user-controllable information displays, superior graphics, data integration from spreadsheets, databases, and text, and drill-down features. Design guidelines have been primarily based on using whatever features the vendor provides.

Academics have grappled with definitional characterizations (Turban and Watson 1989), organizational implementation approaches (Rockart and DeLong 1988), and identification of research directions (Zmud 1986) for EIS. However, there has been little theoretical development which directly informs the conceptual characterization of EIS and guides their design (Mannheim 1989, Carlson and Widmeyer 1990, Westland and Walls 1991). Even though The Institute of Management Sciences has had a special EIS track in its yearly DSS Conference since 1986 (Fedorowicz 1986, El Sawy 1987, Weber 1988, Widmeyer 1989, Volonino 1990, Ziggs 1991), the theoretical concepts underlying EIS design have remained relatively undeveloped. Our aim is to delineate such theoretical foundations.

This paper articulates a concept of design theory in the context of the IS discipline. To set the stage for design theories, we begin with a discussion of explanatory and predictive theories. Next we move to the nature of design theories in general, follow this with a discussion of design theories in the information systems context, and conclude with a definition of a design theory for VIS.

2. Design as Synthesis

Scientists try to identify the components of existing structures. Designers try to shape the components of structures. (Alexander 1969)

Although the above statement is from an architect discussing static structures, it is also pertinent to dynamic systems like information systems. Science is the human activity by which theories are generated and tested. It involves both formulating conjectures about how things in the world affect one another and testing these conjectures by careful observation and experiment. While science is concerned primarily with analysis, design is oriented toward synthesis. However, a scientist is a designer when he designs instruments to test theories. Because he applies scientific theory in implementing his designs and the scientific method to test them, a designer is also sometimes a scientist.

Science may be viewed as the process of designing theories. (Dubin, discussed in detail below, describes the general properties of a design for a theory.) The design process is analogous to the scientific method in that a design, like a theory, is a set of hypotheses and ultimately can be proven only by construction of the artifact it describes. The feasibility of a design can, however, be supported by scientific theory to the extent that the design embodies principles of the theory.

In general, the purpose of a theory is prediction and/or explanation of a phenomenon (Dubin 1978). Natural science theories pertain to the physical or biological world and explain relationships among certain aspects of the natural world and/or predict the behavior of certain aspects of that world. Social science theories perform the same function for the behavior of people either individually or in groups.

An explanatory or predictive theory can be considered to have seven components (Dubin 1978): (1) units whose interactions are the subject of interest; (2) laws of interaction among units; (3) boundaries within which the theory is expected to hold; (4) system states within which the units interact differently; (5) propositions or truth statements about the theory (laws are a subset of propositions); (6) empirical indicators related to the terms in the propositions; and (7) testable hypotheses incorporating empirical indicators.

To make these ideas more concrete, examples are provided in Tables 1 through 3. Table 1 summarizes an example of a descriptive theory from the social sciences taken from Dubin (1978). Table 2 gives an example of a predictive theory from the natural sciences (Shortley and Williams 1965). Table 3 gives a hypothetical example of a descriptive theory from the IS discipline. (Note that, even though it deals with system development, this is not a design theory.)

There are, of course, many different conceptions of theory. Nagel (1961) maintains that a theory has three components: (1) an abstract calculus which is the logical skeleton of the explanatory system, and that “implicitness” defines the basic notions of the system; (2) a set of rules that in effect assign an empirical content to the abstract calculus by relating it to the concrete materials of observation and experiment; and (3) an interpretation or model for the abstract calculus, which supplies some flesh for the skeletal structure in terms of more or less familiar conceptual or visualizable materials. Nagel’s abstract calculus corresponds to Dubin’s propositions and his set
of rules assigning empirical content correspond to Dubin’s empirical indicators. Component (3) is the set of logical statements with descriptive names of units included.

Popper (1968) would consider Nagel’s view to be too limited and places additional requirements on theories: (1) confirmational theories of should only count if they are the result of risky predictions; (2) every good theory is a hypothesis—the more a theory forbids the better it is; (3) every genuine test of a theory is an attempt to refute or falsify it; and (4) confirmatory evidence should not count except when it is the result of a genuine test of the theory.

Kuhn (1970) was concerned primarily with the evolution of scientific “paradigms” rather than with the structure of theories themselves. Paradigm (and later “disciplinary matrix”) refers to the “world view” of a scientific community. The components of the matrix which correspond most closely to Dubin’s view of a theory are “symbolic generalizations” (e.g., $f = ma$) and “metaphysical paradigms” (e.g., “heat is the kinetic energy of the constituent parts of bodies”).

3. The Distinctive Features of Design Theories

4. The Nature of Design Theories

The primary difference between natural and social science theories and design theories is in how they deal with potential behavior or goals. Goals are meaningless in natural science theories. Electrons do not have a goal of changing energy levels. The only goals which exist in this sphere are those of the theorist who is constructing a theory (e.g., to receive a Nobel prize). Social science theories, on the other hand, may deal with goals as objects of study. For example, a theory might be devised about the goals of an organization which hypothesizes that an organization of a particular type has certain goals, or that an organization with a strong leader is more likely to achieve stated goals. However, the purpose of the theory is to explain why specific goals exist or predict outcomes associated with goals. The purpose is not to achieve those goals.

The purpose of a design theory is to suggest goals that are meaningful in a theory in which the design theory is defined by Dubin, Nagel, Popper, or Kuhn. For example, while organization theory is a social science theory concerned with explanation and prediction, management theory is related to design theory because it is concerned with how managers can achieve their goals.

The following statements characterize design theories. (1) Design theories must deal with goals as contingencies. While goals are extrinsic to explanatory and predictive theories, they are intrinsic to a design theory. A simple explanatory law is of the form “Y causes X”; a corresponding design rule would be “If you want to achieve goal X, then make Y happen.” For example, $F = ma$ is a natural science law; a corresponding design rule might be: “If your goal is to accelerate mass M = m at rate a = F, then apply force F = ma.” (2) A design theory can never involve pure explanation or prediction. If it explains, it explains what properties an artifact should have or how an artifact should be constructed. If it predicts, it predicts that an artifact will achieve its goals to the extent that it possesses the properties prescribed by the theory, or to the extent that the methods prescribed by the theory are used to construct the artifact.

(3) Design theories are prescriptive. They integrate explanatory, predictive, and normative aspects into “can” and “will” design paths that realize more effective design and use.

(4) Design theories are composite theories which encompass kernel theories from natural science, social science and mathematics. The prescriptive plane provides the common ground for integrating these different types of theories.

(5) While explanatory theories tell “what is”, predictive theories tell “what will be”, and normative theories tell “what should be”, design theories tell “how to/ because”. Although normative theories are also concerned with goals, they are distinct from design theories. Normative theories concern the task and activity toward a particular goal (e.g., a firm should maximize profit) while design theories deal with how to achieve a goal.

(6) Design theories show how explanatory, predictive, or normative theories can be put to practical use. If an artifact which embodies the laws of interaction of an explanatory or predictive theory is designed and constructed, and that artifact satisfies its design requirements, then it provides a measure of empirical support for the theory.

(7) Design theories are theories of procedural rationality (Simons 1981). The objective of a design theory is to prescribe both the properties an artifact should have if it is to achieve certain goals and the method(s) of artifact construction. Artifact properties should be derived from design theory. Design theories involve both the application of scientific theory and the use of the scientific method to test design theories. Since the artifacts which result from the design process are constructed of elements from the natural and social worlds, they are subject to the “laws” which govern these worlds.

Therefore, design theories may borrow from natural and social science theories. Relationships between the properties of an artifact and level of goal attainment are determined by natural and social laws. This is obvious in the case of an artifact subject to physical laws such as a system of pulleys. It is less obvious but equally true in the case of an artifact subject to social laws such as a political system. An information system obviously has elements of both kinds of artifacts and so is subject to both kinds of laws.

If it is to be a good theory (Nagel 1961), a design theory must be subject to empirical refutation. An assertion that possession of a particular set of attributes will enable an artifact to meet its goals can be verified by building and testing the artifact. A hypothesis that a certain method will result in an artifact which meets its goals can be verified by using that method to build the artifact and testing the artifact to see whether it satisfies its goals. Clearly, then, prototype construction is a major aspect of design theory research.
B. Design Theories and Systems

As researchers in the IS discipline, we are concerned with the design of systems. A system is composed of interrelated components which may be subsystems or non-system components. The design of a system is the design of components and their relationships (Churchman 1971). A system design theory should tell us how to establish relationships between components of a system to achieve a specific result. Design theories must address the question of how to combine components and relationships to make subsystems and how to combine subsystems and relationships to make systems.

To the extent that one subsystem of a system can be designed in isolation from other subsystems, a design theory for that subsystem can be developed in isolation from other design theories. Systems are decomposable to the extent that they can be separated into independent subsystems. Consider a stereo phonograph system. The design of the turntable is relatively independent of the design of the amplifier which is relatively independent of the design of the speakers. These subsystems are not completely independent, since the turntable must provide a current which the amplifier can process and the amplifier must generate a signal of sufficient power to drive the speakers. However, given these constraints, one is free to design the electric motor to drive the turntable and the electromagnet to drive the speaker. Furthermore, different natural science theories apply to different components—for example, while angular momentum might come into play in turntable design and acoustics is important in speaker design, neither of these affects amplifier design. However, an overall theory of stereo system design would encompass all of these areas.

It should be noted that design theory is not the same as systems theory. The objective of systems theory is to identify properties of systems common to all types of systems and to use these properties to understand and describe systems (von Bertalanffy 1973).

C. A Formal Definition of a Design Theory

Our goal is to articulate the nature of design theories by emulating Dubin’s (1978) delineation of the nature of another kind of theory (i.e., explanatory and predictive theories). Since “design” is both a noun and a verb, design is both a product and a process. As a product, design is “a plan of something to be done or produced”; as a process, design is “to plan and proportion the parts of a machine or structure that all requirements will be satisfied”. Thus a design theory must have two aspects—one dealing with the product and one dealing with the process of design. Obviously, these aspects cannot be entirely independent, since the design process must yield the product to be designed.

The first component of a design theory dealing with the product of design is a set of meta-requirements which describe the class of goals to which the theory applies. We use the term “meta-requirements” rather than simply requirements because a design theory does not address a single problem but a class of problems. The second component is a meta-design describing a class of artifacts hypothesized to meet the meta-requirements. We use “meta-design” because a design theory does not address the design of a specific artifact (e.g., payroll system for XYZ Corporation) but a class of artifacts (e.g., all transaction processing systems). The third component is a set of kernel theories from natural or social sciences which govern design requirements.

The final component is a set of testable design process hypotheses which can be used to verify whether the meta-design satisfies the meta-requirements.

The second aspect of a design theory deals with the design process. The first component of this aspect is a design method which describes procedure(s) for artifact construction. The second is a set of kernel theories from the natural or social sciences governing the design process itself. These kernel theories may be different from those associated with the design product. The final component is a testable design process hypotheses which can be used to verify whether or not the design method results in an artifact which is consistent with the meta-design. The components of an information system design theory (ISDT) are summarized in Table 4. The relationships among these components are depicted in Figure 1.

Since relational database theory (Codd 1970) is probably the most completely developed example of a design theory in the information systems discipline, we use it to illustrate design theory components. Meta-requirements are the elimination of file insertion, update, and deletion anomalies. A meta-design consists of a set of tables in third (or higher) normal form. Testable design process hypotheses typically take the form of theorems and proofs. A normalization procedure would be a design method. Relational algebra would be a kernel theory for the design method. Testable design process hypotheses would be concerned with showing that the normalization method results in normalized tables. Other examples of ISDTs are discussed below.

4. Information System Design Theories

A. Information System Development

The information system development life cycle (SDLC) is a widely accepted informal information system design theory. The SDLC is usually viewed as consisting of some variant of the following phases: requirements determination, design, construction, implementation, and operation (Mantei and Terrey 1989).

Demarcations between phases of the life cycle are not always exact, Whitten et al. (1988) call requirements determination "system analysis" and define it to be "the study of a current business system and its problems, the definition of business needs
and requirements, and the evaluation of alternatives. This statement echoes Fielden's conception of design as the "definition of a structure." Wetherbe (1984) in fact calls the first phase of the life cycle design of information requirements. Whitten et al. (1988) define design to be "the general and detailed specification of a computer based solution that was selected during system analysis." Thus both systems analysis and design are involved in system definition with the primary difference being that the former is less detailed than the latter. Steward (1987) points out that design is recursive and that design decisions at one stage of the SDLC become requirements at the next. Swanson (1988) proposes yet another view of the SDLC by dividing it into specification, design, implementation, and utilization phases. He argues that each subsequent phase extends the system definition resulting from the preceding phase. Jackson (1983) divides the SDLC into only two phases—specification and implementation saying that "effectively, much of what is sometimes called design is, in JSD (Jackson System Development), treated as an integral part of implementation."

This paper takes the position that design commences immediately after problem identification and terminates when the customer signs off on the system. At each stage of the life cycle, increasingly detailed design decisions must be made. For example, a decision at the requirements stage that a system must provide information about what items are stored in a warehouse does not indicate what files to create, what data to store in records, or what screens will look like. These more detailed design decisions are made later in the life cycle. As another example, a program flowchart does not usually indicate all of the details required to implement an algorithm in a particular programming language. These design details are left to the individual programmer.

B. Examples of Information System Design Theories

Information system design theories (ISDTs) may be developed for any stage of the SDLC. A completely general ISDT would address every stage of the life cycle for any type of information system. Although such a theory does not presently exist, theories which address certain aspects of the design process will be discussed in this section.

Relational database theory has already been mentioned as an example of an ISDT. The Critical Success Factors (CSF) approach to information requirements determination for EIS (Rockart 1979; Rockart and Boll 1981; Butdan 1988) is an example of a method which might be incorporated into an ISDT. Figure 2 shows how this approach maps into the components of a design theory (or ISDT). Neither kernel theories nor testable design product hypotheses have been articulated for this design theory. A possible kernel theory might be Mintzberg's (1973) work on managerial roles. The kernel theories for the design process are also unclear. Testable hypotheses are yet to be formalized. Thus far, testing of the CSF design method has been via informal case studies of use in the field.

Another example of an approach which could be developed into an ISDT is a model of information system dependability (Walls 1985). Meta-requirements for this theory are IS dependability objectives such as security, accuracy and availability. The meta-design is a cost effective set of preventive, detective and corrective controls. A kernel theory is mathematic reliability theory. A set of testable design product hypotheses is embodied in a quantitative model of dependability. The design methods include a morphological approach for identifying controls (Zwicky 1969) and a method of pairwise comparisons for obtaining model parameters (Saaty 1988), both
of which are derived from kernel theories. Design process hypotheses were tested via application to a large-scale case.

C. IS Design Theories and IS Generators

ISDTs are relevant to those software products available in the commercial marketplace which might be called IS generators. MIS generators (e.g., FOCUS) provide the capability to create and update files and to generate reports. DSS generators (e.g., IFPS) provide such features as the ability to perform Monte Carlo simulation and calculate net present value. EIS generators (e.g., COMMANDER EIS) provide features such as the ability to display data in graphical form and to access databases external to the organization.

The capabilities of these tools as well as others used to construct information systems, should be derived from an underlying theory of the design process they are intended to support. This is not, however, the case. Generic properties of MIS generators have evolved out of vendor efforts to provide productivity tools for both the IS professional and the end user. Generic properties of DSS generators have evolved in part out of the academic environment and in part out of vendor efforts to provide productivity tools to financial professionals. Generic properties of EIS generators have evolved out of vendor efforts to get computers into the executive office.

Design methods used in conjunction with IS generators to develop specific IS should be based upon design theories. This is not the case at present. Methods such as IPO and prototyping are used to determine requirements for specific MISs. Management science modeling techniques and software prototyping guide the development of specific DSS. Methods such as the CSF and SBO (Volonino and Watson 1990) approaches are oriented toward the identification of requirements for specific EISs.

D. Testing of Information System Design Theories

As with explanatory and predictive theories, design theories must be testable. Theories are typically tested by some combination of empirical investigation and mathematical proof. We hold that design theories must be subject to empirical validation. An ISDT can be empirically validated only by constructing an IS based upon its precepts and by conducting experiments with that system. Guidelines for a general two-phased ISDT testing procedure are listed in Tables 5 and 6. In Phase I, the design method associated with the theory is tested by comparing the value of using it with the value of using an alternative method. For example, to test an information requirements determination method (IRDM), the full-fledged IRDM prescribed by the theory might be compared with a partial IRDM. In Phase II, the quality of task performance of subjects who use a prototype system having the full range of capabilities prescribed by the design theory is compared with that of subjects who use a prototype having a restricted set of capabilities.

Thus far we have discussed a general conceptualization of the nature of design theories in the IS discipline. In the remainder of the paper, we use these ideas to develop the outline of a design theory of Vigilant Information Systems (VIS). We contend that such a theory would enable the development of Executive Information Systems, which can enhance the wherewithal of an executive to be an effective leader of the strategic decision-making process in his organization in today's organizational environment.

5. A Design Theory of Vigilant Information Systems

A. Environmental Turbulence and Vigilance

In the 1990s executives will operate in an environment which may be characterized as high velocity (Bourgeois and Eisenhardt 1988), equivocal (Daft and Lengel 1986), and nonlinear (Briggs and Peal 1989). In such a turbulent environment, strategic formation and redirection take place in a more emergent fashion than conventional descriptions of strategic planning suggest (Mintzberg and Waters 1985). Strategic decision-making by executives in conditions of turbulence are heavily based on continuous environmental scanning for relevant information signals (Ansoff 1984). El Sawy (1985) found that, in such environments, scanning is done primarily through access to external information sources, and that executives cultivate their own personalized information systems. Furthermore, the continuous acquisition and interpretation of strategic information is critically important to both early warning about discontinuities and better understanding of strategic threats and opportunities (Ansoff 1984).

The concept of "vigilance" is useful in addressing how an EIS can enhance the effectiveness of executives in identifying and diagnosing emerging strategic problems and opportunities in a turbulent environment. Vigilance refers to (1) the ability to be alert and sensitive to signals of change, (2) the ability to be aware of and respond to environmental changes, (3) the ability to predict and act on the potential for change, and (4) the ability to adjust and adapt to the environment. Vigilance is a key component of strategic management and is critical to the success of organizations in a turbulent environment.
alert and action-directed capability than scanning (Hueber 1984; El Sawy and Pauchant 1988). Our idea of vigilance is different from but related to the concept of "vigilant problem solving" introduced by Janis (1989) in the context of policy making in a political context. Hueber (1984) has elegantly argued that decision-making will be faster and more frequent in the more turbulent post-industrial environment. Qualitatively different organizational decision-making processes that fit this new environment will be required. A decision-making process initiated by the emergence of a strategic threat or opportunity involves both executives and managers. Thus, any initiation of strategic decision-making by an executive would have to include a way of communicating to the manager a trigger for further action. It is also apparent that an executive has a front-end path-finding leadership role that is qualitatively different from the management role. To be successful in turbulent environments, an executive leads, rather than manages (Bennis and Nanus 1985).

We maintain that both the design product and design process aspects of an ISDT must be based on kernel theories from the natural or social sciences. Figure 3 depicts our view of how descriptive empirical research on issue tracking and normative theories of open loop control form the basis of an ISDT for VIS. This view is related to the "three alternative general designs for an IS" discussed by King (1982b). He described (1) a normative design which indicates "how a system should operate"; (2) a descriptive design which depicts "how the existing system actually operates"; and (3) a consensus design which "evolves from the other two as they are discussed and

assessed by potential users." Our concept differs from the preceding in two ways. First, we are interested in normative, descriptive and prescriptive design theories, where King was concerned with design alternatives for a particular system. Second, we maintain that an ISDT should go beyond descriptive and normative theories to provide specific guidance to the design process through a prescriptive mode. In the next two sections, we develop the meta-requirements of an ISDT for VIS using a descriptive theory of issue tracking and a normative theory of open loop control.

B. VIS Meta-Requirements Derived from Issue Tracking Propositions

Issues are events, developments, and trends which have a potential consequence for an organization (Dutton and Webster 1988) and which may be identified as either threats or opportunities (Jackson and Dutton 1988). Strategic issues are those perceived to have a significant impact on organizational performance. The strategic management and organizational decision-making literature agree that both strategic issue identification and strategic decision-making are ill-structured processes and that neither is well understood (King 1982a, b, 1984, 1987). Executives are bombarded by a continuous stream of information which they interpret in various ways. Some of this information helps them to identify and shape issues, the meanings of which are constructed, labeled, and packaged over time. In a strategic decision-making context, issues can be viewed as attention organizers.

Empirical evidence from over 20 case studies suggests that in turbulent environments the strategic decision-making process is most appropriately viewed by the participants as a process of attention to issues with varying and shifting priorities. Even though decisions are made, the focal point of deliberation is the issue rather than one of the many decisions around it (El Sherif and El Sawy 1988).

Issues are dynamic entities which evolve over time. They go through a life cycle from birth to death which consists of four stages: discovery, emergence, maturity, and fading. For example, when specific strategic opportunities or problems materialize through a strategic issue, it has passed from emergence into maturity. Issue management means identifying the issue, dealing with the way it impacts organizational interests, and influencing its evolution to the maximum degree of cost/efficacy (King 1984). Managing the issue life cycle is a way of enhancing the initiation of strategic decision-making.

Development of an ISDT for VIS requires a kernel theory which provides a basis for dealing with strategic issues. A longitudinal issue tracking study conducted by El Sawy and Pauchant (1988) provides such a basis. Subjects in this three-month long study tracked the emergence of cellular telephone technology by scanning sources such as newspapers and magazines. The study showed that issues can be made operational via the concepts of templates, triggers, and matches. These concepts are discussed in more detail in the following paragraphs.

A template is a frame of reference through which a particular issue domain is perceived and is similar to the frame concept of artificial intelligence (Minsky 1975). A template is characterized by a plot, or a narrative outline of its theme; a set of constructs, or verbal descriptions of the N bipolar dimensions along which the plot of the template takes place; and an articulation, or the number of constructs which characterize the template. An example from the cellular telephone tracking study should make these ideas more concrete. In that study, a market template and an application template were identified. One plot was concerned with the dynamics of
the cellular telephone market. Table 7 lists the constructs which defined the market template. Template articulation was N = 8. Relative positioning on the constructs was measured on a quantitative scale (i.e., the “Mean Rating” of Table 7) for comparison purposes.

A trigger is a stimulus which impinges upon a template and which may cause it to shift. A trigger can be described by its information, source, and latency. Trigger information is a brief narrative describing what the trigger conveyed (e.g., “cellular telephones can no longer be competitive in this market”). Trigger source denotes where the information was obtained (e.g., an article in the Wall Street Journal). Trigger latency is the extent to which a trigger impacts further template shifting.

A twitch is a template modification caused by a trigger. A twitch is customarily defined as a short movement with a sudden motion. This term is used to denote the impact of a trigger and to capture the notion that a twitch may be transient and temporary. A twitch is defined by its descriptors, magnitude, and driver. A twitch descriptor is an operator which describes the nature of a twitch. These operators can occur in various combinations including: substitution, modification, which adds a new construct to the template and/or drop an existing construct; articulation, which combine two existing constructs to form a new construct and/or branch an existing construct into two new constructs; and orientation, which change the orientation of existing constructs. A twitch magnitude can be expressed through the aggregation of trigger descriptors. Finally, a twitch driver is an underlying latent construct which drives the template twitch. Among a set of twitch drivers for a template, the most powerful driver can be viewed as the one that most strongly influences the twitching process.

One of the striking findings of the cellular telephone tracking study was that twitchs are much more informative than templates. Latent twitch drivers could not be identified by comparative statics of templates over time. Examination of twitchs made possible a greater degree of interpretation and diagnostic probing of an issue than did examination of templates. In other words, more information was obtained from the change in the change than from the change itself. To use an analogy, acceleration was more informative than velocity. Thus issue tracking is a second-order phenomenon. Table 8 lists issue tracking propositions (ITIP) derived from the preceding discussion.

A vigilant information system (VIS) is one which: enables opportunistic modes of environmental scanning; proactively helps to detect weak signals and discontinuities; initiates further probing based on such detection; and enhances formulation of emerging issues. Combining ITIP1 through ITIP7 and recasting them in a prescriptive mode yields VIS meta-requirements MR1 through MR7 listed in Table 9. (MR4 is derived from open loop control considerations discussed below.)

C. VIS Meta-Requirements Derived from Open Loop Control Propositions

Human choice is a process of drawing conclusions from premises (Simon 1976). Simon suggests that the behavior of a rational person can be controlled by specifying the fact and value premises on which his decisions are based. Premises (in the form of directives, policies and organizational culture) are supplied by an authority process and communicated to the decision maker.

Control can be complete or partial (Simon 1976). For two reasons we hold that control can be only partial for human components in the decision-making process. The first is that a manager who is making a decision has his own premises which may interfere with those supplied by the organization. The manager’s premises derive from both his organizational experience and his more general social experience. The second reason that control is partial is that many of the assumptions upon which a decision is based are equivocal (Daft and Lengel 1986). That is, a particular directive or policy may be ambiguous or open to multiple interpretations.

Generally, there are two types of control: open-loop and closed-loop. The presence of a feedback loop from the managerial process to the executive process provides closed-loop control of the organizational decision-making process. From control theory we know that open-loop control (OLC) systems can respond faster than

TABLE 7

<table>
<thead>
<tr>
<th>Market Template Constructs</th>
<th>Mean Rating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Growing service market</td>
<td>2.07</td>
</tr>
<tr>
<td>Shrinking service market</td>
<td>1.79</td>
</tr>
<tr>
<td>Growing equipment market</td>
<td>2.36</td>
</tr>
<tr>
<td>Shrinking equipment market</td>
<td>2.93</td>
</tr>
<tr>
<td>Expensive to use</td>
<td>3.71</td>
</tr>
<tr>
<td>Cheap to use</td>
<td>2.64</td>
</tr>
<tr>
<td>Expensive to purchase</td>
<td>4.07</td>
</tr>
<tr>
<td>Cheap to purchase</td>
<td>3.29</td>
</tr>
<tr>
<td>Tool</td>
<td>2.43</td>
</tr>
<tr>
<td>Toy</td>
<td>2.64</td>
</tr>
<tr>
<td>Reliable service quality</td>
<td>3.29</td>
</tr>
<tr>
<td>Reliable service quality</td>
<td>2.43</td>
</tr>
<tr>
<td>Service quality</td>
<td>2.64</td>
</tr>
<tr>
<td>General service area</td>
<td>2.43</td>
</tr>
</tbody>
</table>

TABLE 8

<table>
<thead>
<tr>
<th>Issue Tracking Propositions</th>
</tr>
</thead>
<tbody>
<tr>
<td>ITIP1: Executive perception of a turbulent organizational environment can be represented by a set of strategic issues.</td>
</tr>
<tr>
<td>ITIP2: Executive perceptions of issues can be made operational via the concept of triggers, templates and twitchs.</td>
</tr>
<tr>
<td>ITIP3: Strategic issues can be classified according to stages in their life cycle.</td>
</tr>
<tr>
<td>ITIP4: Making strategic issues operational via triggers, templates and twitchs is robust throughout the stages of the issue life cycle.</td>
</tr>
<tr>
<td>ITIP5: Twitches are more informative than templates in detecting weak signals and discontinuities in a turbulent organizational environment.</td>
</tr>
<tr>
<td>ITIP6: Diagnostic probing by executives is a process of “squeezing” problems out of issues and delegating them to managers.</td>
</tr>
<tr>
<td>ITIP7: Executives employ a limited number of heuristics in squeezing problems out of issues.</td>
</tr>
</tbody>
</table>

TABLE 9

<table>
<thead>
<tr>
<th>Meta-Requirements for a VIS</th>
</tr>
</thead>
<tbody>
<tr>
<td>MR1: A VIS should support issue representation in the form of triggers, templates and twitchs.</td>
</tr>
<tr>
<td>MR2: A VIS should support issue management life cycle.</td>
</tr>
<tr>
<td>MR3: A VIS should support problem squeezing heuristic.</td>
</tr>
<tr>
<td>MR4: A VIS should support problem templates which are vision-consistent for the executive and normative-discrepant for the manager.</td>
</tr>
</tbody>
</table>

March 1992
Building Information System Design Theory for Vigilant FIS

TABLE 10
Open-Loop Control Propositions

OLCP1. Open-loop control makes it possible to simultaneously have faster decision-making and decision process stability.

OLCP2. Open-loop control requires that the executive process increases its issue scanning and tracking activity.

OLCP3. Open-loop control does not cause instabilities in the organizational decision-making process when problems are logically consistent.

receives feedback from the managerial process but must instead be more vigilant with respect to the impact of managerial actions on the environment. Since most executives are overloaded with the current task of being vigilant regarding new threats and opportunities, the addition of another significant task must be accompanied by additional support mechanisms.

We can cut the feedback loop in the organizational decision-making process if we assume that the problem templates that are transmitted from the executive to the manager form a logically consistent set. As long as this is true the manager learns a consistent corporate culture and the executive can expect the manager to choose a course of action consistent with the corporate culture. Consider, for example, the trend in American business toward an emphasis on quality. If the organization had previously emphasized cost over quality and the executive starts sending problems to the manager indicating a change toward emphasizing quality over cost, the executive cannot be sure how the manager will choose courses of action to solve problems. In this case the manager must rely on closed-loop control or risk chaotic decision-making.

The preceding ideas form the basis of a normative theory of organizational decision-making in conditions requiring rapid response. Key variables include the degree of feedback from the managerial to the executive process and the degree to which the problem templates transmitted by the executive to the manager is consistent with the organizational culture as perceived by the manager. The feedback variable ranges from closed-loop to open-loop control and the template variable ranges from culture-consistent to culture-discrepant.

There exists empirical evidence suggesting that open-loop control mechanisms are actually used successfully in conditions of rapid decision-making. Bourgeois and Eisenhardt (1988) found that, in high velocity environments, effective firms made strategic decisions quickly and built in schedules, milestones or events that triggered decisions (i.e., "decision execution triggers"). They also found that firms performed better when implementation triggers were articulated at the time a strategic decision was taken. Taken in combination these findings seem to indicate that a form of OLC is at work in these firms.

The preceding discussion yields the three open-loop control propositions (OLCP) listed in Table 10. Recasting these propositions in a prescriptive mode yields MR4 listed in Table 9.

D. Meta-Design Features of a VIS

Having addressed the meta-requirements of an ISDT for VIS, we now turn to a consideration of meta-design. Table 11 lists a set of meta-design features for a VIS required in our definition of an ISDT. Requirements M101 through M103 derive...
TABLE 11
Meta-Design for a VIS

MD01. Template data structure including issue descriptor, multiple critical indicators, executive directives, subordinate manager (response).
MD02. Template add and delete.
MD03. Critical indicator add, delete, and modify.
MD04. Data structure linking sources of information to critical indicators.
MD05. Automatic maintenance of template history.
MD06. Twitch heuristics add, change and delete.
MD07. Directive add, change, delete.
MD08. Template passing to a subordinate manager.
MD11. Automatic periodic monitoring subordinate manager's proposed action.
MD12. Data structure supporting organization values.
MD13. Organization value add, change and delete.

directly from the need to support the triggers, template and switches model. There must be a template data structure which includes an issue descriptor, multiple critical indicators, a directive to a subordinate manager, and responses from the subordinate manager (MD01). A critical indicator is one of a limited number of parameters which describe an issue and which can be used to track it. (See below.) The system must also have the ability to add and delete templates (MD02) as well as the ability to add, delete, and modify critical indicators (MD03).

Requirements MD04 and MD05 are necessary if one is to probe into the causes behind a twitch. This includes the ability to link sources of information or references to them to critical indicators (MD04) as well as automatic maintenance of template history to allow investigation of critical indicator behavior over time (MD05). We assume that the executive uses rules of thumb to detect when an issue changes in importance. Thus the VIS should have the ability to add, change or delete heuristics which determine when a twitch has occurred (MD06).

Support of open-loop control requires that the executive have the ability to pass on to his subordinate manager the information he has which may be useful in taking action based upon the outcome of the issue tracking process. Thus the VIS must provide the ability to add a template a directive to a subordinate manager (MD07) and the ability to pass all or part of a template to him for his action (MD08). In order to track the life cycle of an issue, the VIS must have a capability which permits tracking of the resolution of a problem squeezed out of an issue. Therefore, the system must have the ability for a subordinate manager to add a response to a directive and return it to the executive (MD09), the ability for a subordinate manager to notify the executive of his progress on a directive over time (MD10), and automatic periodic monitoring of an issue to follow up on a subordinate manager's proposed action (MD11).

To aid the executive in enforcement of premise consistency, the VIS should support a data structure for representing the organization's values (MD12), the ability to store, add, change or delete values (MD13), and automatic checking of executive directives for consistency with the organization's values (MD14).

An ISDT should contribute to the development of tools which facilitate the IS development process. Consistent with this perspective, we see the capabilities listed in Table 11 as critical to the design of a VIS generator. Much like a DSS generator which can be used to develop a specific DSS, we envision a VIS generator to be a generalized software product useful in developing a specific VIS oriented toward a particular organization or executive.

From a pragmatic perspective, we believe it is more sensible to augment EIS generators (e.g., Commander EIS) to take on the role of VIS generator than to build an entirely new software product. This could be achieved by adding the capabilities listed in Table 11 to EIS generators. Since both VIS and EIS generators are oriented toward providing information to executives, they are closely related. For example, issues tracked by a VIS are very likely to have information sources accessible via an EIS. Conversely, some issues tracked by VIS will be new goals which can be monitored by an EIS.

E. Testable Design Product Hypotheses for VIS
The meta-requirement and meta-design components of our design theory must be empirically tested by developing and using a specific VIS. Table 12 lists examples of hypotheses about the theory which could be tested. Many of these hypotheses have to do with the feasibility of building such a system while others address the effectiveness of the design product.

F. Information Requirements Determination Method for VIS
The design process component of our design theory for VIS focuses on the information requirements determination stage of the SDLC. Of course there are many other important aspects of VIS design (e.g., database, screen, and algorithm design). Since a significant amount of research has already been done in these areas which is applicable to the detailed design of any type of information system, these issues will not be addressed here.

Four general information requirements determination (IRD) strategies have been identified: (1) asking directly, (2) derivation from the existing information system, (3) synthesis from characteristics of the larger system within which the information system will be used, and (4) prototyping (Davis and Olson 1982). Within each of these strategies there exist multiple information requirement determination methods (IRDMs). Davis and Olson described eight of the most well-known methods:
IRDM for VIS. The CSF approach is based on the premise that information requirements should be derived from an examination of those things which must be done well in order for the organization to be successful (Rockart and Bullen 1981). Based on the literature, we can conclude that the CSF approach is tactical rather than strategic, oriented toward management control, and assumes objectives and goals are known and fixed. Most users of the CSF approach to EIS design report mixed results at best (Burkan 1988; Volonino and Watson 1990).

An IS built using the CSF approach can make the executive aware that a problem related to a goal exists. It does not, however, help him to either understand the cause of the problem or to act upon it. A VIS design theory, on the other hand, requires an IRDM which is oriented toward strategy formulation, is theory based, allows for changes in objectives and goals, and can help the user track and probe issues encompassing both problems and opportunities, and has been validated by a rigorous approach.

The SBO approach overcomes some of the shortcomings of the CSF approach (Volonino and Watson 1990). Because it incorporates the strategic plan into the process of determining executive information requirements, it has a more strategic orientation. It also recognizes the importance of internal linkages between functions as an important factor which must be monitored by an executive. However, the approach still has shortcomings from our perspective. Since it still focuses on monitoring the achievement of goals, it is oriented toward management control. Furthermore, it does not address the question of issue management.

Because it is based upon models of the larger system in which it is embedded, i.e., theories of executive cognitive processing of issues and the normative models of organizational adaptation to a rapidly changing environment, the CAT approach fits into Davis' category (3). However, it has a firm theoretical foundation which distinguishes it from other methodologies in that category.

Following are examples of testable design process hypotheses based on the CAT approach:

PROC 1. It is feasible to design a specific VIS based on the CAT IRDM.

PROC 2. A design for a specific VIS based on an IRDM which uses a combination of issue generating critical events and goals will be judged by the user to be superior to one designed using critical events alone.

6. Conclusion

This paper has presented an approach to building and testing design theories in the information system domain and has outlined a design theory of vigilant information systems intended to provide rigorous and valid guidance to EIS design. It augments the theoretical base underlying EIS, a class of information systems which are critical to strategic decision-making but for which there is currently little underlying theory. The knowledge gained from developing and testing a design theory of VIS should enable us to provide guidelines for more effective EIS design.

While the approach to theory building adopted in this paper was focused on the development of a theory for EIS design in particular, it can also provide a powerful way of constructing design theories for other types of information systems. We hope that it will stimulate IS researchers to build design theories for other types of information systems. Successful construction of design theories will strengthen the endogenous base for theory development in the IS discipline. Typically, theory development in our field has drawn upon paradigms from other disciplines. The field has
now matured to the point where there is a need for theory development based on paradigms endogenous to the area itself. We hope that this paper contributes to that end.

* William R. King, Associate Editor. This paper was received on October 3, 1980, and has been with the authors 4 months for 2 revisions.

References


