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1987

KEY FEATURES FOR PROBLEM FRAMNG DECISION SUPPORT

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ABSTRACT

This paper addresses the concern for improving DSS design and implementation in the areas of problem framing and problem formulation. It relates key principles of DSS development that are based on a cognitive information processing framework with the tasks that are part of a problem formulation process. Furthermore, the paper shows how the components of a DSS can be related to elements of the combined information processing and problem formulation process frameworks.

1. INTRODUCTION

The panel on "Problem Framing DSS" at the 1986 International Conference on Information Systems recognized "the need for addressing various research issues related to isolating and structuring problems in which effective problem framing accounts for a large part of the performance variance in problem solving" (Anthony 1965). While agreeing that a DSS must be extended in order to help managers formulate problems, members of the panel proposed a variety of perceptions of the critical issues to be considered:

1. Multiple problem representations;
2. Environmental scanning and multiple scenario generation;
3. Human-System dialogue and apportionment of cognitive responsibilities between the manager and the system;
4. Understanding of how managers frame problems;
5. Storing, retrieving, and modifying pattern mappings and pattern matching over different DSS sessions.

This direction in DSS research is long overdue, especially in view of the lack of decision support for the intelligence phase of managerial decision making (MDM). DSS involves an effective blend of human intelligence, information technology, and software which interact closely to solve complex problems. The concept of DSS has received considerable attention in recent years among researchers, yet the preoccupation has been to the solution of problems that are assumed to be well-structured, with little or no attention to the formulation of these problems. Concern for problem framing in the design and implementation of DSSs is mirrored by a similar concern regarding managerial decision making processes themselves. Adams, et al. (1985) address the need for more attention to problem formulation and suggests a decision making process framework that emphasizes problem formulation process, as shown in Figure 1. As Mason and Mitroff (1973) point out, a lack of attention to problem formulation raises the risk of an error of the third kind, namely solving the wrong problem.

If, as several studies point out, a DSS must support the "D," that is the managerial decision, then a complete, comprehensive, and systemic DSS must support problem framing as well. This is especially relevant in the sense that the MDM process includes not only seeking answers to questions, but also defining questions where answers may either be known or can be readily obtained. The framework of Daft and Lengel (1986) addresses the need to clarify the nature of managerial situations in terms of equivocality and uncertainty. Equivocal situations need clarification, while uncertain situations need resolution. The information requirements are different for situations that vary in terms of their uncertainty and equivocality. A DSS that supports problem framing is essential in MDM processes which involve high equivocality. Such a DSS is especially important when high equivocality is coupled with high uncertainty. Examples of these MDM situations are strategic planning, technology

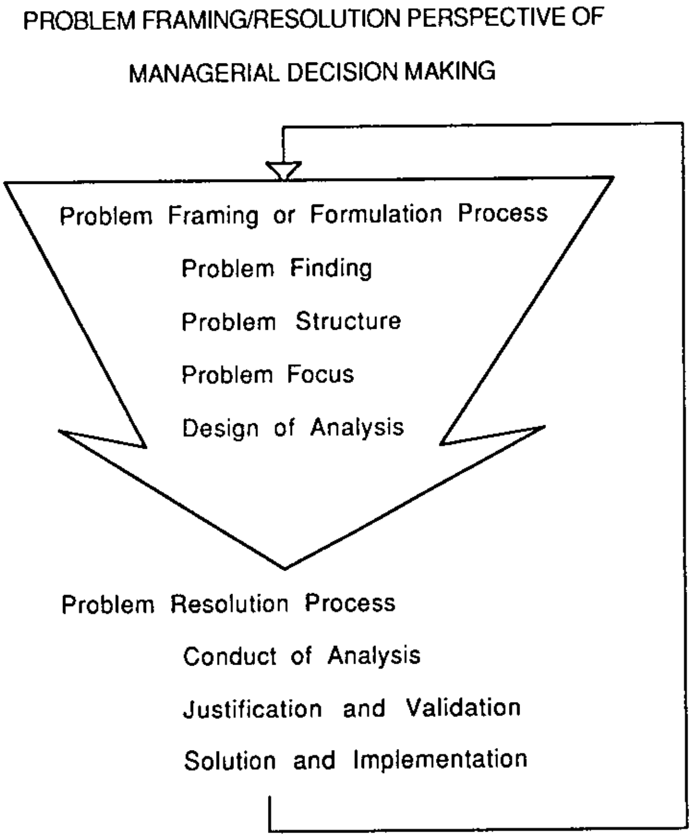

Figure 1. Problem Framing/Resolution Perspective of Management Decision Making (MDM)

[Source: Adams et al. 1985]

planning in rapidly emerging industries, launching of new products, and multinational strategic management.

In this paper we address three key features, identified by Johnson, Severance and Feltovich (1979), which are necessary to ensure that a DSS being used to assist in complex and unstructured problems provides problem framing support as well as the traditional problem solving support in solving complex and unstructured problems. The features are developed from the MDM processes which have been found empirically to be utilized by expert problem solvers. This paper relates the desired DSS features to an understanding of (1) how managers frame problems, especially multiple problem representations and environmental scanning and multiple scenario generation; and (2) how to store, retrieve, and modify pattern mappings and matchings which are consistent with a decision maker's behavior, and especially that of expert problem framing and solving behavior. Further, the paper discusses how these features are useful in defining the arrangement of DSS components, especially in the context of human-system dialogue and the apportionment of cognitive responsibilities between the manager and the system, as proposed in Weber (1986).

2. MDM: FROM A PROBLEM RESOLUTION PERSPECTIVE

Managerial decision making has been viewed as a problem resolution process. Based on a synthesis of this literature, Adams, et al. (1985) provide a problem framing/resolution framework, as shown in Figure 1. In this framework, problem framing consists of problem awareness or recognition and problem formulation and representation. Problem resolution consists of problem solving and implementation. This framework explicitly recognizes the need for a distinction between what has been identified as operand (i.e. problem framing) and respondent behavior (i.e. problem solving) in MDM for problem resolution.

This framework expands the initial definitional stages, allows for the inclusion of specific concepts and methods at the early stages, and provides for the focus on the development of skills required in problem formulation. This added emphasis on the problem framing/resolution tasks within MDM is particularly relevant in designing a DSS which emphasizes the intelligence phase of MDM as called for by Mintzberg, Raisinghani and Theoret (1976), Huber (1981, 1982), and Ariav and Ginzberg (1985). In Section 5 below, we relate components of a DSS and elements of the information processing framework described in Section 3 to the above MDM process framework.

3. MDM: FROM AN INFORMATION PROCESSING PERSPECTIVE

Managerial decision making has been viewed as an information processing activity. A notable model in the context of problem framing and resolution is the information processing model proposed by Johnson, Severance and Feltovich (1979) and Johnson et al. (1981). The utility of this model in explaining human problem solving behavior has been validated in recent, independent amplifications by several authors from a variety of disciplines. These studies address the important issues of expert problem solving behavior and how to transfer the expertise to novice decision makers (Bouwman 1982, 1984; Glaser 1984).

The information processing model describes MDM as consisting of cognitive processes which decision makers use when faced with a decision task environment. The cognitive processes include the formation of cognitive images, invoking a knowledge base, and utilizing a process base.

As Figure 2 shows, *cognitive images* include active hypotheses based on feature, system, and prototype images. The knowledge base is an organized aggregate of information stored in long term memory and referenced by the executive during decision making. *Knowledge base* consists of meta, planning and domain knowledge. Meta knowledge is knowledge about knowledge; it is awareness of what one knows and how the knowledge can be applied to tasks. Planning knowledge is procedural knowledge and consists of goal structures and action sequences which guide the decision process. Domain knowledge for a given task consists of learned facts, laws, principles, paradigms, and heuristics, organized into prototype, feature, and system knowledge. *Process base* is a collection of generalized procedures used by the executive to generate alternate hypotheses about the task and to evaluate these possibilities during decision making.

A DSS can be truly integrated into a decision making system only if the DSS supports all components of the decision making process. Therefore, the focal concept in DSS design must be to create DSS structures and processes that facilitate the decision making process. This article emphasizes this focal concept through the development of some key features for DSS design based on an integration of the problem resolution framework and the information processing framework of managerial decision making.

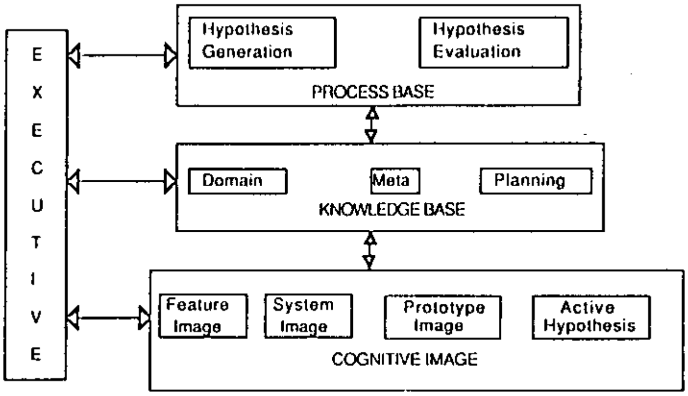

Figure 2. Information Processing Perspective of Managerial Decision Making (MDM)

[Source: Johnson et al. 1979]

4. KEY DSS FEATURES FOR PROBLEM FRAMING AND RESOLUTION

Several approaches to DSS design have been discussed in the literature. These include Alter's taxonomy approach (Alter 1977, 1980), flexible or evolutionary approaches (Keen and Scott Morton 1978; Meador, Guyote and Keen 1984; Moore and Chang 1980), right brain versus left brain DSS (Young 1983), multilevel DSS design architecture (Orman 1984), adaptive design (Sprague 1980; Sprague and Carlson 1982; Stabell 1983), systemic design (Ariav and Ginzberg 1985), group DSS (DeSanctis and Gallupe 1985; Huber 1984), and the decision-oriented approach (Keen and Scott Morton 1978; Keen and Wagner 1979; Klein and Hirschheim 1985; Stabell 1983). The key DSS features presented in detail below, and summarized in Table 1, are aimed at supporting the components of decision processes such that the decision makers can gain significant insights during the decision making process or about the process of decision making.

Table 1. A Summary of DSS Features to Support Components of Information Processing Model of MDM

COMPONENTS OF INFORMATION PROCESSING MODEL OF MDM	KEY DSS FEATURES TO SUPPORT COMPONENTS
COGNITIVE IMAGE	I. A DSS CAN STRUCTURE AND FOCUS COGNITIVE IMAGE BY PROVIDING:
Feature	• Structured checklists and efficient internal organization of task environment information.
System	• Primary and related laws, principles, and abstractions to organize and view information.
Prototype	• Canonical/similar problem instances and prototypical structures.
Active Hypotheses	• Diagnostic reasoning and problem solving skills based on tightly connected schema designed to suggest hypotheses and evaluation procedures.
KNOWLEDGE BASE	A DSS CAN SUPPLEMENT META KNOWLEDGE, PROVIDE PLANNING KNOWLEDGE AND EXTEND DOMAIN KNOWLEDGE BY PROVIDING A DEPOSITORY FOR AND ACCESS TO:
Meta	• Schema of principles and their applications, "rules of thumb", "conditionalized knowledge".
Planning	• Goal structures and action sequences and relating them in the form of the explicit planning structures
Domain	• Canonical problem instances, prototypical structures, structured checklists, and laws/ principles and their abstractions.
PROCESS BASE	A DSS CAN SIMPLIFY EFFECTIVE HYPOTHESES GENERATION AND EVALUATION BY PROVIDING:
Hypothesis generation	• Organizing cues/information and prototypes that suggest hypotheses, thus ensuring the managers do not form hypotheses until suggested by evidence.
Hypothesis evaluation	• Strategies for pruning of hypotheses and, through meta, planning, and domain knowledge bases in conjunction with model bases, suggest procedures for hypotheses evaluation and problem resolution.

I. A DSS Can Structure and Focus the Cognitive Image

A decision maker's cognitive image consists of feature image, system image, prototype image, and active hypotheses. As pointed out by Isenberg (1984), managers add value to sparse facts or cues from the task environment through the use of inferential processes, speculations, hypotheses generation and evaluation, what-if scenarios, and the like. Furthermore, Glaser (1984) points out that the relation between the structure of the knowledge base and the problem-solving process is mediated through the quality of the representation of the problem.

Referring to the internal problem representation as the cognitive structure, Glaser (1984) argues that the quality, completeness, and coherence of the internal representation determine the efficiency and accuracy of further thinking, and that these characteristics of problem representation are determined by the knowledge available to the problem solver and the way the knowledge is organized. The availability of knowledge, including the feature, system, and prototype images, as well as the appropriate organization of these images can form part of the major objectives of a problem framing DSS.

A DSS with an emphasis on the "D" can provide the necessary means to gather and organize the primary and related principles and abstractions that subsume the literal objects in the problem statement, that is the sparse facts or cues from the task environment. In addition to the inclusion of the primary and related principles and abstractions, a DSS can also provide or support the application of this knowledge, in the form of menus of selectable modules (Young 1983), problem-solving walk-throughs, or other methods. A DSS may be designed such that the decision maker uses his tightly connected schema or utilizes the schema designed into the DSS. A DSS-based schema can help the decision maker in acquiring diagnostic reasoning and problem solving skills. This learning phenomenon has been favored by Schein (1969) in the context of his arguments preferring process consultation over other consulting methods.

II: A DSS Can Supplement Meta Knowledge, Provide Planning Knowledge, and Extend Domain Knowledge

Meta knowledge is knowledge about knowledge; it is awareness of what one knows and how the knowledge can be applied to tasks. Meta knowledge is comprised of tightly connected schema and the ability to use problem-solving heuristics and inferential procedures. Meta knowledge, therefore, consists of the decision maker's awareness of the characteristics of his own knowledge, the nature of the processing he does with it, and the limitations he is subject to by virtue of being a fallible information processor (Johnson, Severance and Feltovich 1979; Newell and Simon 1972; Simon 1960).

One of the major objectives of DSS design must be to provide the capability to supplement a decision maker's meta knowledge. Supplemental meta knowledge can include a schema of principles and their applications in the problem formulation and problem solving contexts. Additionally, a DSS can include specific problem solving steps and user-friendly menu-driven modules which link knowledge bases and model bases.

For the expert problem solver, the meta knowledge component of a DSS may serve as a depository of his sophisticated set of "rules of thumb" in problem solving and perhaps as a means for verifying or comparing his analysis and results to those obtained through the use of methods stored in the DSS. For novice decision makers, the meta knowledge component of the DSS provides the necessary support in acquiring and utilizing the available schema of principles and their applications. Further, through a learning and adapting process, the novice decision makers can develop their own meta knowledge skills.

Planning knowledge is procedural knowledge. It consists of goal structures and action sequences which guide the executive or the goal-directed agent during a decision process. For instance, if a software program to solve the transportation problem is viewed as an executive or goal-directed agent, the algorithm used in the program, such as the modified distribution (MODI) method, constitutes the planning knowledge containing goal structures and action sequences. In decision processes, the goal structures are typically organized hierarchically in sequence of goals and subgoals, while action sequences employ conditionals (such as "if-then" statements) to redirect processing as data or cues are accumulated in the cognitive image. It is planning knowledge that enables the expert problem solvers to perform diagnostic and problem-solving reasoning in an orderly fashion and embodies the step-by-step logic often characteristic of expert thought (Bouwman 1982, 1984; Glaser 1984).

The importance of planning knowledge has also been recently documented in Bouwman's studies of expert versus novice decision making in accounting and financial analysis. Bouwman points out that the sequencing of the expert's decision making process is much more complex and totally lacks the repetitive character of that of the novice. Furthermore, Bouwman points out that during the examination of accounting and financial information, novices employ a passive, sequential strategy, whereas the experts rely on a structured checklist, which contains both standard questions (for example, relating directly to goals and subgoals) and conditional questions (such as "if-then" analysis) to guide the analysis.

A DSS can be designed to provide planning knowledge which will permit the creation of an explicit planning structure that shows the decision maker how to think about his problem from beginning to end, from diagnosis to management. A DSS can organize and provide the necessary planning knowledge that includes goals and subgoals and their interrelationships. A DSS can also provide structured checklists of standard and conditional questions and action sequences. An excellent example of planning knowledge that can be incorporated into a DSS is the DuPont Chart showing that linkages between financial ratios and their values established from a company's actual versus planned financial and operating performance results. Similarly, an excellent example of planning knowledge incorporating standard and conditional questions and action sequences is the integration of the PIMS (Profit Impact of Marketing Strategy) findings and relationships among strategy- and business-related variables (Ramanujam and Venkatraman 1984).

Domain knowledge for a given task consists of learned facts, laws, principles, paradigms, and heuristics which are divided into three categories. These are prototype knowledge, feature knowledge, and system knowledge, images of each of which are held by the decision makers in their short-term, working memory as part of their cognitive image. Prototype knowledge consists of canonical problem instances in terms of which task situations are recognized (for example, the prototype managerial problems and the applicable Operations Research/-Management Science tools, as described by Turban and Meredith (1985) and others). Feature knowledge consists of data categories in terms of which a decision task is recognized (for example, assets and liabilities entries in the task of balance sheet preparation, and sources and uses of funds in the task of cash flow statement preparation). System knowledge consists of the fundamental laws and principles which predict and explain the task prototypes (for example, the theorems and principles which guide the formulation and solution of linear programming prototypes).

With respect to problem solving in general, experts have a large store of facts, principles, and prototypes that bear upon a problem (Glaser 1984; Gordon, Miller and Mintzberg 1975). Furthermore, the expert has organized his memory so that the domain knowledge is keyed to sequences of planning steps for the solving of specific problems.

Similar views on domain knowledge have been expressed by Glaser (1984), who refers to domain knowledge as consisting of conceptual knowledge of item content and procedural knowledge of the solution procedures required for solving a particular task form, such as analytical reasoning. Glaser points out that high-aptitude individuals appear to be skillful reasoners because of their level of content knowledge as well as their knowledge of the procedural constraints of a particular problem form, such as inductive or analogical reasoning, and that improvements take place through the exercise of conceptual and procedural knowledge in the context of specific knowledge domains.

Glaser further argues that effective thinking is the result of "conditionalized" knowledge. This is knowledge that becomes associated with the conditions and constraints of its use. As this knowledge is used and transferred to domains of related knowledge, the skills become generalizable. This can lead to intelligent performance, as displayed in the context of novel, "nonentrenched" or "ill-structured" situations (Glaser 1984).

Glaser also emphasizes prototype knowledge, referring to it as schemata which represent knowledge as we experience it: interrelationships between objects, situations, events, and sequences of events that normally occur. Prototypes are frequently experienced situations that individuals use to interpret instances of related knowledge: the cognitive process of integrating new information with prior knowledge. Knowledge of prototypical structures that describe problem situations is often a form of tacit knowledge present in effective problem solvers and skilled learners (Glaser 1984; Gordon, Miller and Mintzberg 1975).

Bouwman (1982, 1984) also found evidence for the utilization of prototype knowledge by the experts; the experts use a list of typical problems during their reasoning process. Furthermore, Bouwman found that experts summarize groups of related findings, thereby eliminating the need to keep track of detailed, individual findings, data, or cues; that is, the ability to recognize, develop, and organize feature image.

These findings, relating to effective problem framing and solving, support the desirability of the above-stated DSS feature, namely to extend a decision maker's domain knowledge. A DSS must provide the decision maker with the capabilities for storing, organizing, retrieving, and utilizing prototype, feature, and system knowledge. Many DSS generators available commercially, such as the Interactive Financial Planning System (IFPS) provide the necessary facilities to support and extend feature knowledge (for example, the universal consolidation facility in IFPS) and system knowledge (for instance, the IFPS/Optimum (Gray 1983; Keen and Wagner 1979). In addition to these readily available packages, a DSS design can provide capabilities to capture and organize a decision maker's own prototype, feature, and system knowledge components of his domain knowledge, thereby alleviating human cognitive limitations on readily accessible long-term memory which typically contains a decision maker's domain knowledge.

III: A DSS Can Simplify Effective Hypotheses Evaluation

As discussed in an earlier section, one of the major components of the information processing perspective of MDM is the process base where decision makers (executives or goal-directed agents) generate and evaluate hypotheses relating to the task environment. Specifically, the process base is a collection of generalized procedures used by the executive or the goal-directed agent to generate alternate hypotheses about the task and to evaluate these possibilities during decision making (Johnson, Severance and Feltovich 1979).

The fact that experts formulate hypotheses and that this constitutes one of the major differences between expert and novice problem solving processes has been verified by Bouwman (1982, 1984) and others. In fact, researchers such as Bouwman, Isenberg (1986), Johnson (1979), and Glaser (1984) have empirically observed that most significant differences between novices' and experts' problem solving behavior occur during the reasoning phase. For novices, reasoning appears to mean deciding when to select what observed fact to define the "main problem." For experts, on the other hand, it is an attempt to develop a "picture of what is going on" or the "relevant picture of the world" through the process of transferring part of "reasoning" to "recognition," thereby generating additional leads and hypotheses for further confirmation and evaluation (Bouwman 1982, 1984).

The DSS feature to simplify effective hypotheses evaluation can reduce or alleviate the differences between the novices' and the experts' reasoning processes. A DSS can store and organize a comprehensive process base and make it readily available and easily accessible to the decision maker. The process base consisting of capabilities for hypotheses generation and evaluation may be developed based on previously or currently available prototype, feature, and system knowledge and must be updated with the decision maker's own cognitive image containing active hypotheses based on his experience and expertise.

Note that the words "simplify" and "effective" are important to hypothesis generation and evaluation. Accordingly, a DSS can structure and focus cognitive image (Feature I) components, namely prototype, feature, and system images. Furthermore, a DSS can suggest strategies for generating and pruning of lists of hypotheses. Also, a DSS can present strategies for grouping and organizing knowledge to evaluate the selected hypotheses.

A DSS which supplements meta knowledge (Feature II) enhances the awareness of one's knowledge. Therefore, a DSS can lead to the generation of effective hypotheses based on tightly connected schema and inferences generated in the context of the knowledge and its structure. This can alleviate the decision maker's temptations to anchor and adjust based merely on events, information, or other stimuli or cues from the task environment.

A DSS which provides planning knowledge (Feature II) can prompt the decision maker to consider issues that are important to appropriate goal structures. Furthermore, a DSS can aid the formulation of effective hypotheses which are based on standard and conditional action sequences. These DSS features can help decision makers in avoiding premature conclusions and biased interpretations.

Finally, a DSS which extends domain knowledge (Feature II) reduces the decision maker's reliance upon a fallible long-term memory, extends the range of prototypes he can consider, and, when necessary, enables him to build an appropriate system image for his problem. Through these avenues of support, a DSS can encourage the decision maker not to hypothesize a prototype until some evidence suggests it, provide him with a rich store of information about the statistical frequency of prototypes, help the decision maker in selecting and limiting the number of active hypotheses and, by using different levels of hypotheses at different points in the decision process, keep the number of hypotheses manageable and simplified for effective evaluation.

5. IMPLICATIONS FOR ARRANGEMENT OF AND INTERFACE BETWEEN DSS ELEMENTS

The three key DSS features described above have significant implications for the arrangement of and the interface between or the links among the DSS components. These components and their arrangement have been the topic of interest among many researchers. Sprague (1980) provides a technical view of this DSS aspect in terms of DSS generators, DSS tools, and the specific DSS. Ariav and Ginzberg (1985) argue for a systemic view for the arrangement of and interface between DSS components. Bonczek, Holsapple, and Whinston (1981, 1982) describe DSS as consisting of the language system, the problem processing system, and the knowledge system, all of which are vital to provide proper interface among the user, the data, and the models. Our proposals for key DSS features extend these conceptual foundations to the arrangement of DSS components, as shown in Table 2 and discussed below.

Efficient access and the ability to manipulate the knowledge base by the decision makers are imperative for effective cognitive image formation and the eventual problem framing and resolution. The interface (labeled I in Table 2) between the cognitive image and the knowledge base implies that DSS design must provide for user-friendly, easy-to-use methods for retrieval of domain, meta, and planning knowledge from the knowledge base to be commonly found in a DBMS.

The interface (labeled II in Table 2) between the knowledge base and the process base is a topic of interest to many researchers. (An issue of *Decision Support Systems* [Vol. 2, 1986] was devoted to MBMS and contained several perspectives on the links and interfaces between DBMS and MBMS.) One of the important considerations in DSS design is to provide a proper interface between DBMS and MBMS such that the user utilizes appropriate data from the knowledge base and applies them to models form the process base in an efficient and effective manner. Furthermore, DSS design should include provisions for automatic or user-initiated update of the knowledge base (DBMS) or the process base (MBMS) or both, based on accumulated experience or expertise.

Table 2. Interfaces among DSS Components: Integrating the Information Processing Model of MDM into Problem Framing and Resolution Framework for Decision Support

COMPONENTS OF INFORMATION PROCESSING MODEL OF MDM	PROBLEM FRAMING • Find/Focus • Structure • Design analysis	PROBLEM RESOLUTION • Conduct analysis • Justify/Validate • Solve/Implement	INTERFACES AMONG DSS COMPONENTS: DBMS, MBMS, AND DSS USER
COGNITIVE IMAGE Feature System Prototype Active Hypotheses	Abilities for: —Multiple problem representations —Access to a large number of patterns or prototypical data combinations —Hierachical and/or random access at all image levels —Generate/evaluate relevant hypotheses	Interactive —Modeling and analysis tools —Evaluations and/or predictions from active hypotheses —Justify/validate based on what-if and sensitivity analysis —Model/predict impact of solution	I III IV
KNOWLEDGE BASE Domain Meta Planning	—Store domain, meta, planning knowledge for interpreting cues/information —Organize to permit ready access at all levels of detail & cross references	—Store models based on domain, meta, & planning knowledge —Multiple scenario generation —Store/retrieve/modify problem solving patterns	II
PROCESS BASE Hypothesis generation Hypothesis evaluation	—Suggest hypotheses based on prototypes and task data —Problem definitions based on relevant, proven hypotheses	—Provide prediction from hypotheses —Resolution based on prediction from proven hypotheses	

Ad hoc modeling and prototyping are representative of the elements of interface (labeled III in Table 2) between the cognitive image and the process base in the information processing model. We have already discussed how the process base can provide valuable assistance in cognitive image formation for problem framing and problem solving. Among the important considerations for the interface between the user, his cognitive image, and the process base are: (a) assistance in model formulation; (b) support in suggesting prototype models; (c) capability for ad hoc modeling; (d) ability to capture user's modeling protocol and, thus, the experiences and expertise for future use; and (e) efficient and easy access to the process base on an as-needed basis, especially for decision situations such as meetings of committees, department, board of directors, and other group and organizational decision settings.

The interface (labeled IV in Table 2) among all three components of the information processing model represents the core or kernel or essence of decision making. Obviously, all of the considerations discussed in the context of the other pair-wise interfaces apply to this interface as well. Furthermore, DSS design must also consider interconnections and interactions between systems (Ariav and Ginzberg 1985). One aspect of the interaction patterns is the transmission of decisions from one DSS to another such that the other DSS may evaluate the impact of the decision on its own environment; that is, the process of decision channeling (Keen and Scott Morton 1978) or decision sharing (Ariav and Ginzberg 1985) and the subsequent "interorganizational sensitivity analysis." These are some of the key considerations in DSS design, which are aimed at a decision process-oriented DSS that will have an organizational identity by virtue of the DSS being organizationally integrated and not isolated.

6. CONCLUDING REMARKS

This article has presented some key DSS features that are derived from a cognitive information processing perspective of MDM and relates them to tasks in problem framing/resolution. We believe that a DSS providing these key features will lead to decision-centered or decision process oriented support for MDM. Furthermore, such a DSS, in our opinion, will be valuable to the decision makers in conducting and managing the stages of problem awareness, recognition, and framing, as well as problem solving and implementation.

It is clear that many areas of further research originate from our propositions in this article. More precise managerial and technological definitions of the interfaces between the cognitive image, the knowledge base, and the process base are required. Empirical research on the usefulness of the key features for DSS design is needed. Such empirical studies may be conducted in different task environments, by different decision makers or experts in identical task environments, in group problem situations, and so on. Also needed are empirical and case studies to verify the applicability and usefulness of the key DSS features in organizational settings.

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