A NEW APPROACH TO PROBLEM DEFINITION

Using Information Objects

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More than 50% of the errors in systems design and development stem from not getting requirements right initially. This article proposes a new taxonomy, using three fundamental information objects, to help the systems developer better understand decision problems and determine their information requirements.

THE FUNDAMENTAL OBJECTIVE OF developing information systems is to provide relevant and timely information to decision makers. To design such systems, the developers—possibly the end users—need to have a clear understanding of the decision problem being supported. They must determine the information requirements vis-à-vis the decision problem and its component tasks. This involves identifying and detailing the nature of the data to be stored, the decision process involved, and the presentation or report form (i.e., information output) to organize the data. Thus, to successfully design a support system, the systems developer needs an organized means of examining decision problems and their inherent information needs.

The difficulty is that the majority of the frameworks and taxonomies for classifying and describing problems, in the IS context, provide inadequate characteristics of the information needed to support the decision maker for the problem under consideration. They furnish a general characterization of problems on the basis of their structure and programmability, and are useful for understanding the nature of the different types of problems faced by decision makers. However, most taxonomies offer little guidance to the systems developer for identifying and determining the characteristics of information that would have to be provided in a support system for the problem under consideration.

Such guidance is essential to providing IS support that effectively assists decision makers in their problem-solving and decision-making endeavors. This fact is central to the process of systems development, irrespective of whether the problem is structured or unstructured, or at the managerial control, operational control, or strategic planning level of management activity. Obviously, this does not imply that the type of management activity or problem structure is not critical to the overall information requirements process. Rather, it means that the development of a system requires the delineation of more fundamental aspects of information needed for supporting the decision maker.

To provide such a characterization of decision problems, a taxonomy for characterizing problems from a systems development context is illustrated. The taxonomy is based on the information needs that characterize problems. Such a taxonomy of problems provides guidance to systems developers for determining the information requirements for decision making.

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CATEGORIZING IS PROBLEMS

The importance of understanding the decision problem and the problem type for which support systems are to be designed has been underscored by various researchers in the field of information systems. In 1933, John Dewey characterized the notion of a decision "problem" as any situation that perplexes and challenges the mind. He also realized the importance of the "nature" or "type" of problems and argued that it critically affected the process of thinking (about solutions).

Gorry and Scott Morton, in their seminal research framework for management information systems, proposed a similar taxonomy, using the terms *structured* and *unstructured* to categorize problems.

It is possible to classify any problem in terms of the three fundamental information objects.

Unstructured problems can be further classified as either semistructured or ill-structured. Whereas structured problems are characterized by closed constraints, a limited problem space, and unique or optimal solutions, ill-structured problems are complex, novel, rarely recur in the same form, lack a systematic basis for dealing with them, have open constraints, and require the use of ad hoc schemes, judgment, or some form of informal sensing or intuition. Semistructured problems fall in between structured and ill-structured problems.

Most extant taxonomies of decision problems emphasize the nature or character of a problem in terms of its structure or its programmability, rather than characterizing the information needed to support it. Consequently, the extant classifications seem to fall short in their ability to provide any useful guide for developing systems. The critical aspect of developing effective systems to support decision makers at various levels of the organization is the provision of timely and relevant information. The best way of classifying problems, insofar as systems development is concerned, would be to characterize them in terms of their information requirements at the outset.

AN ALTERNATIVE TAXONOMY OF PROBLEMS

A taxonomy is a formal system of nomenclature to classify entities or groups based on some assumed or presumed relationships. A taxonomy implies an inherent characterization of the entity or group in an attempt to delineate features that are peculiar to the entity and could assist in identifying and classifying any new occurrences of it. Thus, a taxonomy of problems provides some characterizing properties that should form a common basis for classifying and describing decision problems. In this article, the classifying descriptors of information requirements for the decision problem under consideration will be termed *information objects*. To provide such unique and identifying features of problems with respect to their information requirements, it is important to understand the nature of problems and the information needed to support problem solving.

Systems designed to support structured versus unstructured (semistructured/ill-structured) decision problems are characteristically different. Systems supporting structured decision problems need standard models based on established relationships between data items. They are often inflexible as to the content and format of their reports. Thus, in most situations, the data used by these systems is aggregated to a high degree; a detailed break up of data need not be stored within the system's data base. (This isn't to say that there are no structured decision problems that would require disaggregated data. In fact, there are examples of operational decisions that require detailed data.)

In contrast, systems designed to support decision makers dealing with semistructured or ill-structured problems are often characterized by flexible access to data and a considerable degree of flexibility in building models, aggregating data, and designing report formats. Such flexibility might require that data be stored in the system's data base in its atomic form. (Many extant systems fail in this regard. Data that is highly aggregated produces a great deal of inflexibility in building models and reports, which is one reason there is user impatience with such systems. This is especially critical for problems in which the decision makers must rely on their subjective judgment when building decision models requiring the combined use of atomic data items.)

Consider the example of a decision problem for which a systems developer needs to identify and develop information requirements. To provide effective support to the decision maker, the developer needs to gain a detailed insight into the problem and to identify and detail objects, such as the information output (e.g., report forms) presented to the decision maker, the data that is necessary to create them, and the transformation or steps that need to be applied to the data for creating the reports. These are all different aspects of the information requirements for the decision problem

EXHIBIT 1 Characteristics of Information Objects

Decision Problem	Information Object		
	Data	Decision Process	Report Form
Accounts receivable; order entry; inventory control	Quantifiable, Aggregated	Programmable, Prescriptive, Formula, Structured	Objective, Planned, Known
Production scheduling; short-term sales forecasting; advertisement allocation			
Election returns analysis; capital structure allocation; R&D planning			

under consideration. They are information-oriented characteristics that aid in understanding the overall information needs of the problem. Thus, in general, it is possible to classify any problem in terms of the following three fundamental information objects. These are listed and explained, at this stage, without regard to the sequence in which they might be used for systems development. Exhibit 1 characterizes each of these three objects: data, decision process, and report form.

Data Objects. The data object refers to the raw data that is known or thought to be relevant to the decision being made. Data may not be accessible in its atomic form because of timing considerations, storage or data base costs, or simply because it is not gathered and stored.

Data should be stored in its basic (raw) form whenever it is cost-effective, especially if the system is to provide support for unstructured decision problems. The unit sales price and the number of units of any product are examples of pure atomic data. The total units of all product sold by a salesperson and the total sales of one product, on the other hand, would be examples of higher levels of aggregated raw data.

Report Form. Data needs to be organized before it can be presented to the decision maker. The report form object refers to the organization or form of this presentation or information output. Literally, this has to do with the appearance (and implicitly, the organization) of the data needed by a decision maker.

The report form provides the means for presenting the relevant data. Report forms may vary from preplanned or standardized forms to ad hoc forms defined by the decision maker on demand. A standardized form is characteristic of report forms needed for structured decision problems. Some examples of structured report forms are sales analysis, inventory status, budget variance, and lot-scheduling reports. Ad hoc report forms created on demand for strategic planning and capital budgeting are characteristic of unstructured decision problems. In the case of unstructured decision problems, the nature of the report forms may not be known or may be partially known. In addition, the relationships between the data items useful for such problem solving may not be well understood, or some of the necessary data items might be unavailable or missing, requiring the use of subjective judgment. Long-range production planning, capacity planning, capital budgeting, and strategic planning are examples of the various levels of difficulty encountered while defining report forms for unstructured decisions.

Decision Processes. To process data and present it as information in such a way that the result is

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directed toward the decision to be made, it is necessary to define specific decision models or procedures. These decision processes could allow optimal solutions to be derived and presented automatically. On the other hand, they could provide simulation-type decision models that present choices or allow comparisons of different alternatives, or even give models based on the subjective judgment of the decision maker. Thus, the decision process object refers to the actual steps and models for obtaining information on the specific problem being considered. In the case of structured problems, the decision process would comprise unambiguous decision rules and models. The data and relationships between data are explicitly known, and the process or procedure for aggregating the data is transparent.

For unstructured problems, the decision process may not be understood well enough to allow a stable preestablished procedure. The absence of any preestablished process is especially true of ill-structured problems, which are considered to be inherently "fuzzy," needing extensive use of human experience and judgment. Also, decision procedures that are applied to an ill-structured decision problem at one instance in time may never be used in the same form. The environmental factors affecting such a decision are inherently unstable. This volatility can produce unanticipated changes to the problem space itself. Consequently, systems need to incorporate a great deal of flexibility in terms of building and explicating decision procedures and models.

APPLICATION OF THE TAXONOMY

Consider the decision problem of inventory reordering. This problem uses some very specific data, an unambiguous decision model, and an explicit report form to present the results to the decision maker. The data information object includes data such as the current inventory level, the reorder point, the annual demand, the ordering cost, the holding cost, and the lead time. The decision process involves the use of the EOQ (economic order quantity) model. The resulting output can be displayed in a simple inventory report form. There may even be a decision process that triggers an inventory reorder report each time the stock goes below the reorder point.

In contrast, the management-level decision problem of "allocation of advertising costs" between existing products is more complex in terms of its information needs. All complex decision problems consist of numerous problem tasks or subproblems. Thus, to enable easier identification and analysis of the relevant information objects that characterize a problem, it needs to be decomposed into its subproblems or problem tasks. The main reason for this is that the notion of a problem is in itself very tenuous. Thus, to be useful in an IS development context, the proposed taxonomy of problems would have to be applied to specific problem tasks that are components of a larger decision problem. Once the problem is decomposed into its component tasks, the three information objects—report form, decision process, and data—can be identified and analyzed for each of them.

Because the role of advertising is to increase a product's demand, the advertising cost allocation problem may be considered to consist of certain specific subproblems such as:

- *What do we want to achieve (goal)?* Is the goal of advertising to increase market share, improve profitability, or increase the sales to cost ratio for each product?
- *What is happening (performance measurement)?* Is the product profitable? Is there a demand for the product?
- *Why is it happening (performance diagnosis)?* How are the competitors doing with the same product? What is happening in the industry (mid- to long-term trends)? How much are competitors investing in advertising for the product? Are we spending enough on advertising?
- *What should be done about it (decision)?* What are the options? How much should be put into product A versus product B? What are the estimated cost/benefits of each of the options?

Although, this list is not exhaustive, it illustrates how complex the advertising allocation decision can become. The proposed taxonomy of problems allows the systems developer the opportunity to look at each of the subproblems directly in terms of their data, report, and decision process requirements. It may be possible to obtain complete knowledge of the report-form and decision-process objects for some of these subproblems, whereas for other subproblems it may only be possible to incompletely or partially understand these two objects. Of course, the assumption here is that the data involved is available and can be stored in the system.

Thus, for example, the subproblem 3—performance diagnosis—would require data such as industry forecasts for the product, competitors' expenditure on advertising, and performance in

EXHIBIT 2 Information-Oriented Taxonomy of Problems

Problem Type	Information Object		
	Data	Decision Process	Report Form
Structured	Known*	Known	Known
Semistructured	Known*	Partially Known** or Unknown***	Partially Known** or Unknown***
Ill-structured	Known*	Unknown***	Unknown***
	Operational Control, Management Control, and Strategic Planning		
	Management Activity		

Notes:

* Obviously the "data" has to be available for it to be known.

** Partial knowledge implies an incomplete understanding of the "form" or "process." This also indicates that some human judgment is involved.

***No knowledge (unknown) regarding the "form" and "process" simply implies that human judgment is predominantly involved and is probably always necessary.

terms of the product—possibly obtained from 10K reports or other sources. This problem task would require incorporating some standard allocation models, such as the sales-response model, some gaming models, and a competitive market share model. At the same time, there is the need for flexibility when building decision models based on human judgment and the ability to test the alternatives. The reports simply could be forecasts from industry, economic trends, or financial information.

Finally, it should be underscored that the systems developer can use the taxonomy to delineate problem tasks into categories. This categorization would depend on how much knowledge is then available (obtainable), about the nature of the data, report forms, and decision processes involved for each problem task. In cases where the knowledge is incomplete, the systems developer would have to provide flexibility to allow the user to generate decision models and report forms.

In this way, the proposed taxonomy can provide the systems developer with a way to obtain information requirements for the decision problem under consideration. In this sense it is more useful than extant taxonomies for classifying problems. Furthermore, it is essential to point out that the taxonomy is not, in itself, an information requirements analysis approach; but it does provide systems developers a more effective means of organizing and delineating their understanding of the information requirements for given decision problems.

Some Implications for Systems Development

Exhibit 2 shows how the three information objects—data, report form, and decision process—can be incorporated within the Gorry and Scott Morton framework for information systems. It shows how this alternative taxonomy of problems fits within the more general framework of problems. Furthermore, it also

illustrates the pragmatic usefulness of the information requirements-based characterization of problems proposed by the taxonomy.

The taxonomy suggests that structured decision problems are characterized by the fact that all three of the information objects—data, report form, and decision process—are unambiguously available and known. If only one of the three objects is known and there is incomplete or no knowledge about the others, then the problem is unstructured. Furthermore, if the data and the report-form objects are known, and there is an incomplete or partial understanding (knowledge) of the decision process (requiring the need for some human judgment to arrive at the final decision), the decision problem can be classified as semi-structured. If data is known and there exists incomplete or partial knowledge of both the decision process and the report form, the decision can be classified as ill-structured.

The taxonomy set forth in this article suggests some important implications for information systems development in two areas.

The systems developer can use the taxonomy to delineate problem tasks into categories.

Structured or Unstructured Problems. Characterization of problems as structured or unstructured has little value to the systems development process. The taxonomy for problems presented in this article adds substance to the notion of problem structure, thereby providing a more concrete avenue to understand and identify information requirements for a given decision problem.

For a decision problem needing IS support, systems developers may need only work with the three basic information objects. Without concerning themselves about the structure or nature of the problem, systems analysts can proceed by identifying the data, the report form, and decision process needs of the problem or its constituent problem tasks. This provides systems developers with a tool for initial analysis of a problem, allowing them to generate a set of information requirements that can be quickly implemented in a prototype system. Furthermore, the taxonomy is especially helpful in structuring and understanding the information needs for semistructured and ill-structured problems.

Information Requirements Definition. Information requirements of problems can be easily described using the three information objects—data, report form, and decision process. The question of what data is to be stored—whether it is to be all data items, some atomic data, or some levels of aggregated data—must be decided on the basis of the designer's knowledge of all three information objects. The data is assumed to be always available, but it may not be relevant to the problem.

In instances where there exists only partial or incomplete knowledge about the decision processes and report forms for a given problem task, the systems developer would first describe all known parts of them. Some decision processes and report forms would require the use of human judgment. In such cases, the systems developer should provide adequate flexibility for developing judgmental decision models/processes and for consolidation of data into meaningful report forms.

Obviously, the more detailed the data stored in the system, the better the decision maker's ability to remain flexible in formulating decision models and designing report forms. For problems requiring human judgment, the systems builders would have to make detailed data available, provide multiple analysis and decision models, and facilitate the development of ad hoc procedures.

CONCLUSION

Although different taxonomies of problems have been proposed in the past, none has attempted to characterize problems on the basis of their information requirements. Taxonomies of problems based on their structure and their relationship to management activity do not seem to provide any guidance for developing information systems. They assist in characterizing problems in terms of information needs in a very general and tenuous way.

The alternative taxonomy of problems developed in this article, however, provides an information-oriented characterization for all decision problems. Three fundamental information objects are used to describe and classify decision problems and their constituent problem tasks. The three information objects allow the systems developer to achieve an understanding of the information requirements of different decision problems in an evolutionary fashion.

Systems developers can incorporate this taxonomy as the front end of a rapid prototyping process (or other evolutionary development processes), allowing the eventual identification and structuring of report forms and decision processes and the finalizing of input data that would be needed. ▮