Correct and complete information requirements are key ingredients in planning organizational information systems and in implementing information systems applications. Yet, there has been relatively little research on information requirements determination, and there are relatively few practical, well-formulated procedures for obtaining complete, correct information requirements. Methods for obtaining and documenting information requirements are proposed, but they tend to be presented as general solutions rather than alternative methods for implementing a chosen strategy of requirements determination.

This paper identifies two major levels of requirements: the organizational information requirements reflected in a planned portfolio of applications and the detailed information requirements to be implemented in a specific application. The constraints on humans as information processors are described in order to explain why "asking" users for information requirements may not yield a complete, correct set. Various strategies for obtaining information requirements are explained. Examples are given of methods that fit each strategy. A contingency approach is then presented for selecting an information requirements determination strategy. The contingency approach is explained both for defining organizational information requirements and for defining specific, detailed requirements in the development of an application.

Strategies for information requirements determination

by G. B. Davis

An information system should meet the needs of the host organization it serves. The requirements for the information system are thus determined by the characteristics and procedures of the organizational system. But correct and complete information requirements are frequently very difficult to obtain. Simply asking prospective users of the information systems to specify the requirements will not suffice in a large percentage of cases. There are three major reasons for the difficulty in obtaining a correct and complete set of requirements:

1. The constraints on humans as information processors and problem solvers.
2. The variety and complexity of information requirements.
3. The complex patterns of interaction among users and analysts in defining requirements.

The constraints on humans as information processors and problem solvers are important in understanding fundamental human difficulties in responding to requests for requirements. This paper will emphasize these basic constraints while recognizing that the basic constraints based on human limitations are expanded and extended by the other two factors.

The three reasons for difficulty in arriving at correct and complete requirements for information systems suggest that there should not be a single approach to requirements determination that is applied to all projects. Instead, there should be several general approaches or strategies that may be used. These strategies reflect the best approaches to use considering the alternative set of conditions that may apply.

Within the broad outlines of a strategy for information requirements determination, one or more methodologies may be selected from among a number of such methodologies that have been developed for use in eliciting and documenting information requirements. Broad claims often are made about a methodology's use under all conditions. Rather than being universal, however, a methodology tends to work best with one of the broad strategies. Thus, having selected a strategy, the analyst needs to decide which of the alternative methodologies is appropriate to the strategy.

This paper seeks to bring more order into the information requirements determination process by clarifying the two levels of requirements needed, by explaining the difficulties of information requirements determination in terms of some fundamental limitations of humans as information processors and problem solvers, and by proposing a contingency theory for selecting a strategy for information requirements determination.

The two levels of information requirements

There are two levels at which information requirements need to be established in order to design and implement computer-based information systems:

1. The organizational information requirements to define an overall information system structure and to specify a portfolio of applications and data bases.
2. The detailed information requirements for an application.

The requirements determination process is similar for the two levels, and the same set of requirements determination strategies apply to both. However, the scope and detail differences in requirements suggest that some methods of requirements determination are more suitable for the less-detailed, broader-scope, organization-level information requirements, whereas other methods may be more suitable for the more detailed application information requirements. Some methodologies can be applied to requirements determination at both levels.

organization-level information requirements

An overall plan or master plan is necessary for the formal information system in an organization (often termed a management information system). The master plan is important to information system development for reasons such as the following:

1. The plan defines an overall information system structure or architecture.
2. The plan establishes a portfolio of applications that will provide complete coverage of needs.
3. Clear, well-defined boundaries are established for individual applications. The interfaces among applications are defined so that applications can interact as part of the larger system.
4. The plan specifies an orderly development of applications based on organizational priorities and the necessary physical development sequence.
5. If the overall system architecture includes shared data bases, sets of data requirements are defined.

application-level information requirements

Information requirements determination at the organizational level is a key element in developing an information system master plan. The information requirements determination process obtains, organizes, and documents a complete set of high-level requirements. The requirements are factored into subsystems (a portfolio of applications) that can be scheduled for development. The boundaries and interfaces of the application subsystems are defined at this level, but there are no detailed requirements.

An application is a subsystem of the information system. It is the planning and management unit for development, operations, and maintenance. An application system provides information processing for an organizational unit or organizational activity. The organizational unit or organizational activity is the utilizing system or object system for the information system. The objectives and boundaries of the application and requirements for interfacing with other applications are established by the information system master plan. The information requirements determination process at the application level defines and documents specific information content plus design and implementation requirements.

There are essentially two types of information system application requirements: social and technical. The social or behavioral requirements specify objectives and assumptions such as the following:

- Job design objectives
- Work organization design objectives
- Individual role assumptions
- Responsibility assumptions
- Organizational policies

The technical requirements specify the outputs, inputs, stored data, and processes. A significant part of the technical requirements are associated with data—its structure and format. Data represents things and events, and data structure models the users' and developers' understanding of the structure of things and events. The format of data is the window by which users of the data see things and events. Format is thus constrained by the structure. Format is important in directing attention, showing relationships, providing readability, and assisting in deriving results and implications.

The use of data bases has increased the importance of the data structure requirements because the data structure is relatively permanent, whereas format is relatively easy to change. Five general information requirements for design of a data structure are given below. The first four of these requirements provide information for design of a logical data structure; the fifth requirement is necessary for the selection of a suitable physical data structure.

1. Identification of things and events included within the scope of the object system
2. Relationships among things and events
3. Attributes of things and events
4. Validation criteria for data items
5. Characteristics of use of data structure

Usable information content for human users of information is dependent not only on the availability of the data (via the data structure), but also on the presentation format. Significant differences in use of data, in errors in use, and in perceived value of the data can result from differences in presentation format. Examples of requirements relative to format and comments on the need for each are given in Table 1.

Constraints on humans as specifiers of information requirements

Humans appear to be so versatile with respect to information use that human constraints or limitations are frequently ignored. Yet, these limitations mean that "asking" users their information require-

Table 1 Requirements for presentation format

Presentation format specification	*Comments*
Layout of data	The layout of data has a significant influence on information use. The order of presentation, the location on the page or screen, and use of boxes, arrows, and underlines affect the utilization of data on output media.
Directions and labels on data	Directions for use and labels on data can aid and encourage (or discourage) use or misuse.
Level of summarization of data	Summarized data is generally more useful in decision making, but detailed data is needed to provide users with assurance that summarization has not obscured important characteristics.
Processes performed on data	Output should be processed with subtotals, percentages, differences, measures of central tendency, etc., if users need to perform these processes.
Selection/query paths for data	The methods that are provided for selecting data and obtaining results from queries will affect the use and misuse of data.
Tracing data and processing trail pointers	It should be possible for a user to trace from a report back to the constituent data items or from a data item forward to its inclusion in summaries. Also, it should be possible to verify any computations or classifications of data.
Data connections and relationships	It should be possible for a user to explore related data if use of the initial output suggests it.

ments will not necessarily yield a complete and correct set of requirements. These limitations are (1) humans as information processors, (2) human bias in selection and use of data, and (3) human problem-solving behavior.

humans as information processors

Humans make use of three memories in information processing:[1,2] external, long-term, and short-term. External memory consists of external media such as a pad of paper or a chalkboard. A visual display device can also be used as external memory. The human brain has both long-term and short-term memory. Long-term memory has essentially unlimited capacity. It requires only a few hundred milliseconds to read (recall) from it, but the write time (commit to memory) is fairly long. The short-term memory is human processor memory. It is very fast, but small in capacity. A computer analogy is register or cache memory. The short-term memory is used in human information processing for operations such as compute and compare. Its limitations may affect human ability to define requirements.

The capacity of short-term memory has been characterized as "seven plus or minus two."[3] The 7 ± 2 refers to chunks of data. A chunk may range from a single character to a visual image. Thus, a telephone number of seven digits may fill short-term memory during dialing, or the images of seven faces may be stored during human processing to select a person.

The limits of short-term memory affect the information requirements obtained whenever the process being used to elicit requirements uses only short-term memory (such as an interview unaided by external storage). The user being interviewed cannot hold a large number of items in short-term memory for discussion or analysis purposes and is therefore limited in processing responses. The short-term memory limitation may also affect the number of requirements that users define as important. In various processing activities using short-term memory, the user may have selectively emphasized a few items of information and recorded these in long-term memory as being the most important. These few may be the only ones recalled when a question is asked.

The short-term memory limitations can be significantly reduced by the use of external memory to store data being processed and by the use of methodologies that systematically elicit and record small numbers of data chunks.

human bias in selection and use of data

There is substantial evidence to show that humans are not unbiased in their selection and use of data.[4,5] Some of the behavior resulting in bias is summarized in Table 2. The net effect on the determination of information requirements is a significant bias toward requirements based on current procedures, currently available information, recent events, and inferences from small samples of events. The analyst and user who understand these biases may compensate for them; a significant method of compensation is to provide a structure for problem solving.

human problem-solving behavior

Problem-solving concepts from Newell and Simon are task environment and problem space.[6] The task environment is the problem as it exists; the problem space is the way a particular decision maker represents the task to work on it. The information requirements task environment is the determination of information requirements for an organization or for an application. The problem space in this case is how a particular analyst or a particular user formulates a representation to use in working on the problem of information requirements. Having a structure for thinking about a problem allows a more efficient solution procedure. Methodologies for information requirements determination provide such a structure for the problem space (Figure 1).

A concept related to the problem space is bounded rationality. Humans have a limited capacity for rational thinking; they must

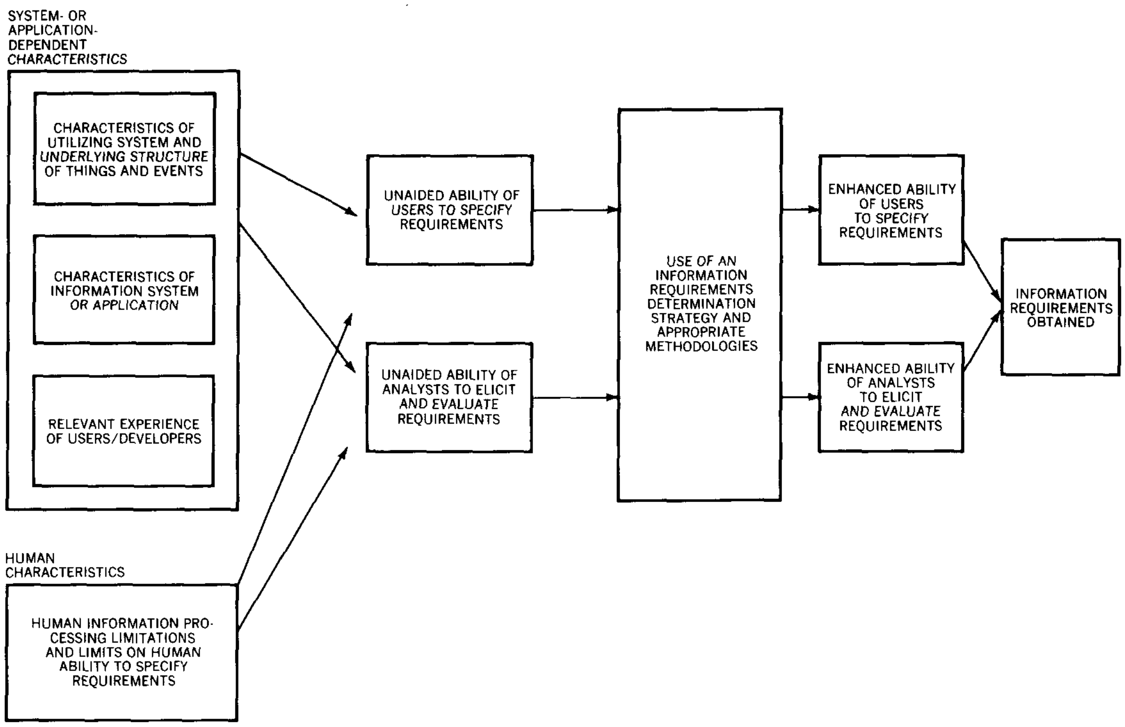
Table 2 Human bias in selection and use of data

Human biasing behavior	*Explanation and effect on information requirements determination*
Anchoring and adjustment	Humans tend to make judgments by establishing an anchor point and making adjustments from this point. Information requirements from users will tend to be a result of an adjustment from an anchor of the information currently available.
Concreteness	Decision makers tend to use only the available information in the form it is displayed. They tend not to search for data or transform or manipulate data that is presented. For information requirements determination, this means that requirements provided by users will be biased by the information they already have about their requirements and the form of this information.
Recency	Humans are influenced more by recent events than by events of the past. In defining information requirements, users will be biased by those events that happened recently. An information need that was experienced recently will be given greater weight than a need based on a less recent event.
Intuitive statistical analysis	Humans are not good as intuitive statisticians. For example, humans do not intuitively understand the effect of sample size on variance and therefore draw unwarranted conclusions from small samples or a small number of occurrences. This is an important limitation because many organizational phenomena occur at a fairly low rate. Also, there is a tendency to identify causality with joint occurrence and assign cause where none exists. These limits of humans in processing low-occurrence data and in identifying causality may result in misjudging the need for information.

generally construct simplifications in order to deal with it. Rationality is thus bounded or limited by the use of a simplified model that does not correspond exactly to the real situation. Other limitations on the problem space are human processing capabilities and other factors such as training, prejudice, custom, and attitude.

Procedures for determining information requirements apply bounded rationality. They tend to use a somewhat simplified model of the organization and its information requirements. The completeness and correctness of the requirements obtained are thus limited not only by the model, but also by the training, prejudice, custom, and attitude of users and analysts involved in the process. The effect of bounded rationality on information requirements analysis is demonstrated in the behavior of system analysts. A characteristic of

Figure 1 Effect of application characteristics, human characteristics, and information determination strategies and methodologies on information requirements obtained



proficient system analysts is that they have learned to use a general model to bound the problem space and aid in an efficient search for requirements; poorly rated analysts have a poorly developed model and, therefore, a poorly developed search procedure in the problem space.[7] Also, the highly rated analysts consider organizational and policy issues in establishing requirements; the low-rated analysts do not include these issues in their problem space. The results suggest the need for analyst training in formulating and using a problem space and in considering important nondata issues such as context, organizational policy, and roles.

Methods and methodologies for use in information requirements determination

A *method* is defined as an orderly or systematic procedure; a *methodology* is a set of methods and techniques. The terms are frequently used interchangeably.

Based on human limitations, an information requirements determination methodology should meet certain needs:

1. Assist an analyst to constrain and structure the problem space. It is estimated that analysts spend 75 percent of their time on this activity.[8]
2. Assist in searching efficiently within the problem space. It should aid in discovering requirements that are not obtained by anchoring and adjustment and in overcoming short-term memory limitations in human information processing.
3. Assist in overcoming biasing factors such as recency, concreteness, and small samples.
4. Provide assurance that requirements are complete and correct.

Methodologies differ in the amount of structure provided. Some provide conceptual structure but little process and documentation structure; others provide detailed structure for all tasks and all documentation. The importance of detailed structure may vary with different circumstances. For example, analysts and users with little experience and expertise may find detailed structure very useful; analysts and users experienced in the application area and able to define requirements may find detailed structure in a methodology to be inhibiting and frustrating.

Strategies for information requirements determination

A strategy was defined earlier as an approach for achieving an objective. Strategies are general approaches; methods and methodologies are the detailed means for doing it. There are four strategies for determining information requirements: (1) asking, (2) deriving from an existing information system, (3) synthesis from characteristics of the utilizing system, and (4) discovering from experimentation with an evolving information system.

In a specific case, one of the strategies may be used as the primary strategy; others may be used as supplementary strategies. The set of four strategies is applicable both to organizational information requirements determination and to application requirements. For each strategy, there are a number of methods and methodologies that are in use (or have been proposed). In the discussion of strategies, some methods or methodologies will be used as illustrations; no attempt will be made to provide a comprehensive list.

In addition to strategies and methods for eliciting requirements, there are also strategies and methods for obtaining assurance that requirements are complete and correct and that systems as implemented meet those requirements.[9] A complete strategy for information system analysis, design, and implementation should include both an eliciting strategy and a quality assurance strategy. The selection of an assurance strategy has been described elsewhere; this paper focuses only on the strategy for eliciting or determining the information requirements. It is not directed at life cycle or other methodologies for assurance.

Table 3 Methods for asking users to define information requirements

Asking method	*Description*	*Conditions suggesting use*
Closed questions	Each question has a defined set of possible answers. Respondent selects from the set of responses.	When set of factual responses are known or respondent may not be able to recall all possibilities. Analyst must have knowledge of possible responses.
Open questions	No answers provided. Respondent is allowed to formulate response.	When feelings or opinions are important or when respondent has knowledge and ability to formulate responses.
Brainstorming	Group method for eliciting wide variety of suggestions by open flow of ideas.	Used to extend boundaries of problem spaces of participants and elicit nonconventional solutions.
Guided brainstorming	The IDEALS method[10] is an example. Participants are asked to define ideal solutions and then select the best feasible ideal solution.	Used to guide brainstorming to "ideal" solutions. Useful where participants have system knowledge, but may be locked into an anchoring and adjustment behavior.
Group consensus	Delphi method and group norming are examples. The participants are asked for their estimates or expectations regarding significant variables.	Used to arrive at "best" judgmental estimate of variables that are difficult or impossible to estimate quantitatively.

Asking

In a pure asking strategy, the analyst obtains information requirements solely from persons in the utilizing system by asking them the requirements. From a conceptual standpoint, the asking strategy assumes that users have a satisfactory way to structure their problem space and that users can overcome or compensate for biases due to concreteness, recency, and small sample size. Anchoring by users in formulating responses is assumed to yield satisfactory results. These conditions may hold in very stable systems that provide users with a well-defined structure or in systems whose structure is established by law, regulation, or other outside authority. There are a variety of methods for carrying out an asking strategy. Table 3 summarizes some methods with comments on conditions that suggest their use.

If a pure asking strategy is followed, one or more of the asking methods is used to elicit requirements, and analysis is limited to consistency checks as requirements are documented. The asking methods listed in Table 3 can also be used in conjunction with other strategies.

Deriving from an existing information system

Existing information systems that have been implemented and have an operational history can be used to derive requirements for a proposed information system for the same type of organization or for the same type of application. The types of existing information systems that are useful in deriving requirements are

1. Existing system that will be replaced by the new system
2. Existing system in another, similar organization
3. Proprietary system or package
4. Descriptions in textbooks, handbooks, industry studies, etc.

With regard to human problem-solving behavior, deriving from an existing information system is an explicit use of anchoring and adjustment. Users and analysts explicitly choose an existing system as an anchor and adjust the requirements from it. Deriving information requirements from an existing information system or application has also been termed a data analysis approach[11] since the data inputs and outputs of the existing system are the focus of analysis. Personnel in the utilizing system are asked to specify changes from the existing data outputs.

If the information system is performing fairly standard operations and providing fairly standard information for utilizing systems that are stable, the use of an existing system as an anchor is conceptually appropriate. In application systems for some well-defined functions such as payroll, data analysis of an existing system can be a useful primary method. In the early application of computers to organizational transactions and accounting systems, derivation of requirements from the processing performed on the data provided by the existing system was used widely. Also, data analysis of existing systems may be useful as the major method in situations where the objective is to improve processing functions but not the basic information content.

Some analysts use data analysis of the existing system as a secondary method for deriving requirements. In this case, to avoid being overly influenced by the concreteness of the existing system, they prefer to delay its use until after their primary analysis method has provided an initial set of requirements.

Synthesis from characteristics of the utilizing system

Information systems provide information services to facilitate the operation of systems (object systems) that utilize the information. The requirements for information thus stem from the activities of the

Table 4 Characterization of methods for information requirements determination

Method	Primary requirements orientation	
	Organization	Application
1. Normative analysis	X	
2. Strategy set transformation	X	
3. Critical factors analysis	X	
4. Process analysis	X	
5. Decision analysis		X
6. Socio-technical analysis		X
7. Input-process-output analysis		X

object system. This suggests that the most logical and complete method for obtaining information requirements is to develop them from an analysis of the characteristics of the utilizing system. This approach may overcome the biases of anchoring, concreteness, recency, and small sample size by providing an analytical structure for the problem space of the user or analyst. Since requirements are derived from an analysis of the utilizing system, existing reports, recent events, or numbers of occurrence are not significant. The object system analysis is therefore appropriate when the utilizing system is changing or the proposed information system is different from existing patterns (in its content, form, complexity, etc.) so that anchoring on an existing information system or existing observations of information needs will not yield a complete and correct set of requirements.

Several methods have been proposed for performing information requirements determination from object system analysis. Although useful at both organizational level and application level, each method has a primary orientation. They can be characterized as shown in Table 4.

normative analysis

Normative analysis methods are based on the fundamental similarity of classes of object systems. These fundamental characteristics lead to a prescribed or normative set of requirements. Analysis then concentrates on tailoring the normative requirements to meet nonstandard needs. An example of a normative methodology is Business Information Analysis and Integration Technique (BIAIT™).

BIAIT was developed in the 1970s by Burnstine.[12] The starting point for analysis is an order, the driving force in an organization. An order may be to supply a space, a skill, or a thing. Seven questions are asked with respect to the order:

1. Bill or accept cash?
2. Deliver in future or immediately?
3. Need history of customer buying behavior?
4. Negotiated or stipulated price?
5. Rent or sell?
6. Track product sold or not?
7. Made to order or provided from stock?

These seven questions about an order, each with two possible answers, define 2^7 or 128 theoretical combinations of responses, but there are about 60 feasible combinations. The responses define a cell that has associated with it four lists of generic requirements:

1. Common business functions
2. Information processing requirements
3. Business objectives
4. Occupations

The generic model is customized and labeled with the function names unique to the industry and business. The prescribed generic requirements are examined to see if and how they apply. From the customized model, reports, measurements, and data requirements can be derived.

A normative methodology such as BIAIT can be used at the organizational requirements level, at subsystem level, and application level. The methodology operates at a fairly high level and is probably most useful for organizational-level requirements or for categories of standard application requirements.

The advantages of a normative prescriptive method are the structure it imposes on the process and the completeness that can be obtained. It is especially useful for an analyst who does not have a good knowledge of the organization or application being studied, since it results in an examination of the normally prescribed information needs. The disadvantage of a normative method for deriving information requirements lies in the generality of the result. Normative requirements usually require adjustment and tailoring to fit specific organizational needs.

strategy set transformation

Strategy set transformation is a methodology primarily for obtaining organization-level information requirements.[13] The information requirements are derived from the objectives of the organization. For example, if an organizational objective is to improve profits and the selected strategy is to change the sales mix to a larger proportion of higher gross margin products, the information system application derived from this objective is a gross margin analysis report.

critical factors analysis

Critical factors analysis is a method for eliciting the significant decisions or other factors that can be used in deriving information requirements. Essentially, the method structures the problem space for finding decision requirements. An example of critical factors analysis is the Critical Success Factors (CSF) method. It can be used at both the organization and application level.

Critical Success Factors[14] is a method of eliciting requirements by asking users to define the factors that are critical to success in performing their functions or making decisions. A small number of critical factors usually emerges from this eliciting process. It requires relatively little effort to arrive at the critical factors.

process analysis

Another approach to synthesis of requirements, called process analysis, focuses on business processes. The idea underlying this approach is that business processes (groups of decisions and activities required to manage each of the resources of the organization) are the basis for information system support. Processes remain relatively constant over time, and the requirements derived from the processes will reflect the nontransient needs of the organization. An example of process-based methodology is Business Systems Planning (BSP). The method is primarily for developing organizational information requirements as part of developing an information system master plan.

BSP is a comprehensive IBM methodology[15] well supported by manuals and instruction. Information requirements are derived from the object system in a top-down fashion by starting with business objectives and then defining business processes. Business processes are used as the basis for data collection and analysis. In interviews to clarify processes, executives are also asked to specify key success factors and to identify problems. Logically related categories of data are identified and related to business processes. This information is used in defining a proposed information architecture. Based on current status and proposed architecture, application priorities are established and migration to data bases planned.

decision analysis

For information requirements determination, decision analysis is performed by steps such as the following:[16]

1. Identify and prescribe decision.
2. Define decision algorithm or decision process. Various documentation methods may be used. Examples are decision flowcharts, decision tables, and decision trees.
3. Define information needed for the decision process.

Decision analysis has been shown to be very useful in clarifying the information requirements with users in cases where the decision process is fairly well-defined. For unstructured, poorly understood decision processes, decision analysis does not appear to perform any better than a data approach. Also, decision analysis does not apply to all applications or all information included in applications.[17]

socio-technical analysis

The socio-technical analysis approach[18] consists of two parts: social analysis and technical analysis. The social analysis is to determine system requirements relative to the social system of the organization, including requirements for the system design and requirements for implementation. The social analysis is performed by studying patterns of social interaction and group behavior in the current system. Analysis methods may include group discussion and group problem-solving processes. Technical analysis is an analysis of variances and control loops that require information.

Socio-technical analysis is oriented to application-level analysis. It is especially appropriate for applications that involve many participants, that include both primary users and secondary users (such as data preparation personnel), or where the application will significantly change the work environment, the social interaction, or the job design.

input-process-output analysis

Input-process-output analysis is a system approach. A system is defined in terms of its inputs, outputs, and transformation processes for receiving inputs and producing outputs. The system approach starts in a top-down fashion on an object system. Subsystems of the object system are analyzed to achieve further subdivision into subsubsystems, etc., until information processing activities are defined as separate activities within a subsystem.

The advantage of analysis based on inputs, processes, and outputs of systems is that it is systematic and comprehensive. By starting at a high level and factoring into subsystems, we can have reasonable assurance of completeness. Analysis can be carried to as low a level of detail as desired. A very comprehensive example of such an approach is the ISAC method. Data flow diagrams are a second example. A more limited methodology is Accurately Defined Systems (ADS).

The Information Systems Work and Analysis of Changes (ISAC)[19] method was developed by a research group at the Royal Institute of Technology and University of Stockholm, Sweden. It is being used in organizations, primarily in Scandinavia. The method is supported by instruction manuals and layouts for graphs, tables, and other documents. The method begins with an analysis (using a system graph) of the activities in the object system. Subsystems are then analyzed in the same way down to the level at which information processing appears as an activity. The information activities are analyzed as systems and subsystems using graphs termed activity graphs. Associated with the activity graphs are tables summarizing need for change, system objectives, social considerations, and properties of the system. The information system and subsystems from the activity graphs are analyzed for information flow and precedence using a system graph called an information graph. These graphs are supplemented by tables for properties, processes, and tasks. The information system is then analyzed in terms of data structures, equipment, program structures, operations, and manual routines.

Data flow diagrams,[20] when used at a high level of analysis, are a graphic method for defining inputs, processes, and outputs and for factoring systems into subsystems. The factoring process is top-down and can be carried to the level of program module specification.

ADS[21] was developed at NCR. It uses a set of five forms with "where from" referencing to define and check completeness of application requirements in terms of outputs, inputs, history data, logic, and computations.

Discovering from experimentation with an evolving information system

Traditional procedures for information requirements determination are designed to establish a complete and correct set of requirements before the information system is designed and built. In a significant percentage of cases, requirements cannot be established correctly and completely. Information system applications based on elicited correct requirements are rejected by users or receive substantial rework to make them fit user needs. There are various reasons why requirements cannot be obtained. Users may not be able to formulate information requirements because they have no existing model (normative, prescriptive, or experiential) on which to base requirements. They may find it difficult to deal in abstract requirements or to visualize new systems. Users may need to anchor on concrete systems from which they can make adjustments.

Another approach to information requirements determination is, therefore, to capture an initial set of requirements and implement an information system to provide those requirements. As the users employ the system, they request additional requirements. The system is designed for ease of change. In essence, after an initial set of requirements provide an anchor, additional requirements are discovered through system use. The general approach has been described as prototyping or heuristic development.[22]

The iterative discovery method for information requirements determination has considerable appeal. However, upon examination, it has both advantages and disadvantages and appears to be more suitable under some circumstances than for others (Table 5).

Selecting an information requirements determination strategy

Four strategies have been described for determining information requirements, with each strategy having a number of methods that

Table 5 Conditions suggesting use or nonuse of iterative discovery method for information requirements determination

Conditions suggesting iterative discovery method	*Conditions not supporting iterative discovery method*
There is no well-defined model of information requirements. Experience of users and/or analysts is insufficient to define requirements. Users' need for information is evolving (such as in managerial or decision support applications).	There is an existing well-understood, well-defined model of the utilizing system and its information requirements. There is need for stability in an information system because of number of users, complex interfaces with outside systems, etc. Examples are major transaction processing systems.

Table 6 Steps in selecting a strategy and methods for information requirements determination

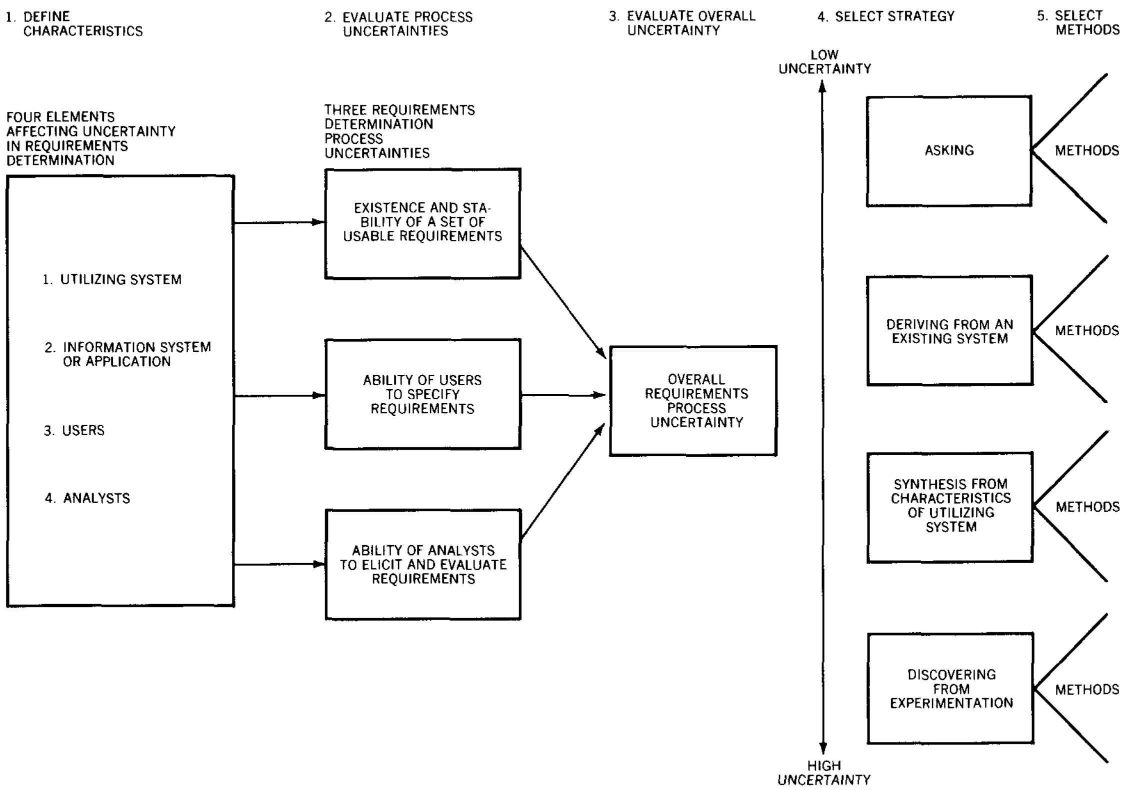
1. Identify those characteristics of the four elements in the development process that affect uncertainty of information requirements determination:
   - Utilizing system
   - Information system or application
   - Users
   - Analysts
2. Evaluate the effect of the characteristics of the four elements in the development process on three process uncertainties:
   - Existence and availability of a set of usable requirements
   - Ability of users to specify requirements
   - Ability of analysts to elicit and evaluate requirements
3. Evaluate the combined effect of the process uncertainties on overall requirements uncertainty.
4. Select a primary requirements determination strategy based on the overall requirements uncertainty.

Uncertainty	*Strategy*
Low	Asking
↑	Deriving from an existing system
↓	Synthesis from characteristics of utilizing system
High	Discovering from experimentation

5. Select one or more methods from the set of methods to implement the primary strategy.

may be employed. In order to provide operational potential to the strategy classification, this section will present an approach to the selection of an appropriate primary strategy. The selection procedure represents a contingency theory, i.e., the strategy selected is contingent on characteristics of the requirements determination environment and process.

Figure 2 Selection of an information requirements determination strategy



The underlying basis for selecting a strategy is uncertainty as to the three requirements determination processes. The bases for the process uncertainty are characteristics of the utilizing system, the information system or application, the users, and the analysts.

five-step approach

The approach to selecting an information requirements determination strategy consists of five steps (Figure 2). The steps represent a series of evaluations to establish a basis for selection. The evaluations are not precise, but do provide for judgment. The steps are listed in Table 6 and explained in more detail below.

Step 1: Identify Characteristics of Elements in the Development Process that Affect Uncertainty. There are four elements in the development process that are relevant to the selection of an information requirements determination strategy: the utilizing system, the information system or application system, the users, and the analysts. The characteristics of these elements determine the expected level of uncertainty with respect to requirements determination as seen in

Table 7 Characteristics of elements in the development process

Elements in development process	Examples of characteristics that:	
	Reduce uncertainty	*Increase uncertainty*
Utilizing system	Stable, well-defined system not in process of change	Unstable, poorly understood system in process of change
	Programmed activities or decisions	Nonprogrammed activities or decisions
Information system or application system	Traditional, simple set of requirements	Complex or unusual set of requirements
	Clerical support system	Management support system
Users	One or few users High user system experience	Many users Low user system experience
Analysts	Trained and experienced with similar information system	Little prior training or experience with similar information system

Table 7. In other words, for each of the elements in the development process, there are characteristics that reduce expected uncertainty as to requirements determination; there are opposing characteristics that increase expected uncertainty.

Step 2: Evaluate the Effect of the Characteristics on Process Uncertainty. The characteristics of the four elements in the development process affect uncertainty of information requirements determination by affecting three process uncertainties, which are

1. Uncertainty with respect to existence and stability of a usable set of requirements.
2. Uncertainty with respect to users' ability to specify requirements.
3. Uncertainty with respect to ability of analysts to elicit requirements and evaluate their correctness and completeness.

The first uncertainty can arise from a number of characteristics of the utilizing system. Some examples are

- Lack of a well-understood model of the utilizing system. This lack may be reflected in confused objectives, unclear organization, and poorly defined operating procedures.
- Lack of stability in structure and operation of the utilizing system.
- Lack of stability in use of information system. Nonprogrammed activity has a low level of predefined structure, and, therefore, changes in user personnel may create unstable use patterns.

- A large number of users can affect the existence and stability of requirements if all users can specify requirements and there is no mechanism to arbitrate differences or achieve consensus.

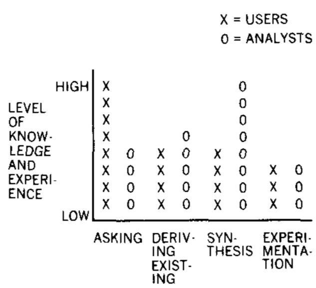
The second process uncertainty is a result not only of human limitations in developing specifications but also of characteristics of the information system or application. Examples are

- Lack of user model of the utilizing system.
- Lack of structure for activity or decision being supported.
- Change in the utilizing system.
- Changes in the use of information.
- A complex system.
- A large number of users which will affect level of participation and users' feelings of responsibility in specifying requirements.
- Type of users doing the specifications. Clerical users may be able to specify procedure requirements, but not overall content; managers may be better in specifying content than procedures.
- Lack of user experience in the utilizing system and lack of experience in type of application being proposed.

The third uncertainty is related to the personal characteristics of the analysts, their general level of training, and prior experience with the same or similar applications. The characteristics of the application that affect users described above also affect analyst performance.

The level of knowledge and experience needed by users and analysts tends to differ for different requirements determination strategies. As illustrated in Figure 3, an asking strategy requires a higher level of user knowledge and experience than an experimental strategy.

Figure 3 Relative estimated level of knowledge and experience by users and analysts to employ the four requirements determination strategies



Step 3: Evaluate the Combined Effect of the Process Uncertainties on Overall Requirements Uncertainty. The expected overall requirements uncertainty could be estimated directly from the characteristics of the object system, the information system, the users, and the analysts. However, it is useful to make this evaluation in two steps—first evaluating the effect of the characteristics of the four elements affecting the requirements determination uncertainty on three process uncertainties and then evaluating the three process uncertainties to arrive at an estimated overall level of requirements process uncertainty.

The expected overall level cannot be estimated with certainty, but the insight gained in the three-step evaluation allows a reasonable basis for selection of a strategy.

Steps 4 and 5: Select a Primary Requirements Determination Strategy and One or More Methods. The strategy is selected based on the level of requirements determination uncertainty.

Table 8 Characteristics for organizational-level requirements

Elements in process	*Characteristics affecting requirements determination uncertainty*
Utilizing system	Stability of system processes Stability in management and control Maturity in use of information systems
Information system	Extent to which higher-level management applications are included in scope of systems Complexity and level of integration of information
Users	Level of experience in utilizing system Experience in planning information systems
Analysts	Experience in planning information systems

When a strategy has been selected, one or more methods are selected for use. The selection of a primary strategy and associated method(s) does not preclude the use of a secondary strategy and other supplementary methods, but it does assist the analyst in understanding how to deal with the expected level of uncertainty as to requirements.

In order to clarify the concept of uncertainty and its effect on information requirements determination, the use of the selection approach will now be illustrated for both the organizational information requirements and application requirements.

The contingency approach applied to organizational information requirements determination

The set of characteristics that apply to organizational-level requirements determination include the items in Table 8.

The characteristic of organizational maturity in use of a computer-based information system reflects the fact that organizations exhibit a learning process. It is not feasible to implement a complex information system in an organization until participants have "learned" on a less complex system. The learning includes organizational and procedural discipline necessary with computer-based systems.

Three examples illustrate the use of the contingency concept for selection of an information requirements determination strategy for the organizational-level information requirements.

1. Company A is a small company with a stable technology that has not used computers before. It expects to apply computer

processing first to accounting and inventory control. It has an analyst with two years experience. In the listing below and in those of the succeeding examples, the second column indicates whether an item adds or reduces uncertainty.

Stable system processes	Reduces
Stable management control	Reduces
Low maturity in computer use	Adds
Clerical level applications	Reduces
Complexity and integration low	Reduces
Experience of analysts	—
Experience of users low	Adds

Based on these characteristics, process uncertainties are classified in the following ways:

- Low uncertainty as to existence and stability of requirements
- Moderate uncertainty as to user ability to specify requirements
- Moderate to low uncertainty as to analyst ability to elicit and evaluate requirements

The overall evaluation is moderate to low uncertainty. Given this level of uncertainty, a requirements strategy might be to derive an initial set of organizational requirements from the existing manual systems.

2. Company B has used computers for traditional accounting but would now like to have management-support applications, decision-support applications, query capabilities, and planning applications.

Stable system processes	Reduces
Management control changing	Adds
Fairly mature in use of computers	Reduces
Management-level applications	Adds
Complexity and integration high	Adds
Experience of users low	Adds
Experience of analysts moderate to high	Adds

An evaluation of these characteristics suggests a moderate to high uncertainty in existence and stability of requirements, a fairly high uncertainty as to user ability to specify requirements, and a moderate to high uncertainty as to analyst ability to elicit and evaluate requirements. Overall, there is a moderately high degree of uncertainty as to requirements determination. The fairly high level of uncertainty suggests a strategy of synthesizing organizational information needs from characteristics of the utilizing system.

3. Company C has a very unstable environment and very poorly developed planning and control information. They wish to

improve their information system to provide better information for planning and control.

Unstable processes	Adds
Management control changing	Adds
Low maturity in use of computers	Adds
Complexity and integration high	Adds
Experience of analysts low	Adds
Experience of users low	Adds

An evaluation of the characteristics suggests a high degree of uncertainty for existence and stability of requirements, user ability to specify, and analyst ability to elicit and evaluate. With this high level of overall uncertainty, the appropriate requirements strategy might be to use experimentation with an evolving system as the primary strategy for determining organizational requirements.

The contingency approach applied to application information requirements determination

The characteristics that may be considered in evaluating uncertainty of requirements processes for an application include the ones in Table 9.

The following examples illustrate the use of the contingency theory to select a requirements determination strategy for an application. In each example, the second column of the list indicates whether an item adds or reduces uncertainty.

1. A balance forward billing and accounts receivable application system for a retail store.

Utilizing system has stable, programmed activity	Reduces
Application has stable requirements with fairly small number of users (in accounting)	Reduces
User personnel familiarity with system is high	Reduces
Analyst familiarity and experience is reasonably high	Reduces

There is very little uncertainty with respect to the requirements themselves, little uncertainty with respect to user ability to provide requirements, and little uncertainty as to analyst ability to elicit requirements and evaluate their correctness and completeness. Given this overall low degree of uncertainty, the analyst may use a primary strategy of asking users to define requirements (using open or closed questions). An alternative primary strategy is to derive requirements from an existing billing and accounts receivable system (existing system in this organization or in another organization).

Table 9 Characteristics for application-level requirements

Elements in process	*Characteristics affecting requirements determination uncertainty*
Utilizing system	Existence of a model of the system Stability of system Nonprogrammed versus programmed activity Stability in information use
Application	High-level versus low-level application Complexity Number of users
User	Experience with utilizing system Experience with application
Analyst	Experience with utilizing system Experience with application

2. An integrated on-line order entry transaction system and management order-tracking application to replace a traditional batch system having little management reporting.

Utilizing system is stable, mainly programmed activity	Reduces
Application has stable requirements for clerical users and moderately stable requirements for management users. Medium number of users.	Reduces
Well-defined model of requirements for order entry procedures;	Reduces
less well-defined model of tracking requirements	Adds
Complex system	Adds
User personnel are familiar with order entry requirements	Reduces
Analyst experience is at least moderate for on-line systems	Reduces

The overall uncertainty level is moderate, based on the evaluation of the three processes:

- Little uncertainty with respect to the order entry functions to be performed and requirements related to these functions. Some uncertainty as to management functions to be supported.
- Little uncertainty as to user ability to define transaction entry requirements and medium uncertainty as to ability to define management reporting. Because of on-line systems, there may also be new social system considerations and human behavior considerations that users cannot define clearly and completely.

- Moderate uncertainty as to analyst ability to elicit requirements and evaluate their correctness and completeness.

Given this overall moderate degree of uncertainty, the analyst may choose to use synthesis from the characteristics of the utilizing system as the primary strategy. Examples of methods appropriate to this situation are

- Input-process-output analysis
- Socio-technical analysis for social and behavioral requirements
- Decision analysis or critical factor analysis for management reporting

3. A management report application for problem identification and problem finding with respect to sales. It includes content of some existing informal, private information systems but does not replace an existing information system application.

Supports mixture of programmed and nonprogrammed activities	Adds
Requirements not stable because they are dependent on experience and decision style of users	Adds
No well-defined model of utilizing system and its requirements	Adds
Users somewhat unsure of requirements	Adds
Analysts inexperienced in specific application because it is unique	Adds

Based on these characteristics, there is the following set of uncertainties with respect to requirements determination processes:

- High uncertainty as to necessary and desirable requirements
- High uncertainty as to user ability to specify requirements
- High uncertainty as to analyst ability to elicit requirements and assess correctness and completeness

The high level of uncertainty suggests a discovery methodology in which requirements are identified iteratively as the application system evolves.

Summary

The problem to which the paper has been directed is the selection of an information requirements determination strategy. In developing the concept of strategy selection, the paper defines two levels of requirements: organizational information requirements and application-level requirements. The constraints on humans as specifiers of information requirements are explored. Four broad strategies for information requirements determination encompass groups of methods. These strategies are (1) asking, (2) deriving from an existing information system, (3) synthesis from characteristics of the utilizing system, and (4) discovering from experimentation with an evolving information system application.

The selection of a strategy is based on uncertainties with respect to information requirements determination processes. The determination uncertainty focuses on (1) uncertainty with respect to existence and stability of a set of requirements, (2) uncertainty with respect to users' ability to specify requirements, and (3) uncertainty with respect to ability of analysts to elicit requirements and evaluate their correctness and completeness. These three uncertainties as to the information requirements determination process are associated with certain characteristics of the utilizing systems, the information system or application, users, and analysts.

The selection of a requirements determination strategy for both the organizational level and the application level is thus based on an evaluation of the characteristics that determine the three areas of uncertainty. The selection of a primary requirements determination strategy that satisfies the level of uncertainty points to a set of methods for use. An analyst may also choose to use other strategies and methods to supplement the primary determination strategy.

CITED REFERENCES AND NOTE

1. G. B. Davis, *Management Information Systems: Conceptual Foundations, Structure, and Development*, McGraw-Hill Book Company, Inc., New York (1974).
2. A. Newell and H. A. Simon, *Human Problem Solving*, Prentice-Hall. Inc., Englewood Cliffs, NJ (1972).
3. G. A. Miller, "The magical number seven, plus or minus two: Some limits on our capacity for processing information," *The Psychological Review* **63,** No. 2, 81–97 (March 1956).
4. Davis, *op cit.*
5. N. P. Vitalari, "An investigation of the problem solving behavior of systems analysts," unpublished Ph.D. dissertation, University of Minnesota (1981).
6. Newell and Simon, *op cit.*
7. Vitalari, *op cit.*
8. *Ibid.*
9. J. D. Naumann, G. B. Davis, and J. D. McKeen, "Determining information requirements: A contingency method for selection of a requirements assurance strategy," *The Journal of Systems and Software* **1,** 273–281 (1980).
10. G. Nadler, *Work Design: A Systems Concept*, Revised Edition, Richard D. Irwin, Inc., Homewood, IL (1970).
11. M. C. Munro and G. B. Davis, "Determining management information needs—A comparison of methods," *MIS Quarterly* **1,** No. 2, 55–67 (June 1977).
12. W. M. Carlson, "Business Information Analysis and Integration Technique (BIAIT)—The new horizon," *Data Base* **10,** No. 4, 3–9 (Spring 1979).
13. W. R. King, "Strategic planning for management information systems," *MIS Quarterly* **2,** No. 1, 27–37 (March 1978).
14. J. F. Rockart, "Critical success factors," *Harvard Business Review* **57,** No. 2, 81–91 (March–April 1979).
15. *Business Systems Planning—Information Systems Planning Guide*, Application Manual, GE20-0527-3, Third Edition, IBM Corporation (July 1981); available through IBM branch offices.
16. R. L. Ackoff, "Management misinformation systems," *Management Science* **14,** No. 4, B147-B156 (December 1967).

17. Munro and Davis, *op cit.*
18. R. P. Bostrom and J. S. Heinen, "MIS problems and failures: A socio-technical perspective; Part I: The causes," *MIS Quarterly* **1,** No. 3, 17–32 (September 1977), and "Part II: The application of socio-technical theory," *MIS Quarterly* **1,** No. 4, 11–28 (December 1977).
19. M. Lundeberg, G. Goldkuhl, and A. Nilsson, *Information Systems Development: A Systematic Approach,* Prentice-Hall, Inc., Englewood Cliffs, NJ (1981).
20. The literature of data flow diagrams and structured analysis is fairly extensive. For example, see T. DeMarco, *Structured Analysis and System Specification,* Yourdon, Inc., New York (1978), and D. T. Ross and K. E. Schoman, Jr., "Structured analysis for requirements definition," *IEEE Transactions on Software Engineering* **SE-3,** No. 1, 6–15 (January 1977).
21. H. J. Lynch, "ADS: A technique in systems documentation," *Data Base* **1,** No. 1, 6–18 (Spring 1969).
22. T. R. Berrisford and J. C. Wetherbe, "Heuristic development: A redesign of systems design," *MIS Quarterly* **3,** No. 1, 11–19 (March 1979).

GENERAL REFERENCES

B. Bowman, G. B. Davis, and J. Wetherbe, "Modeling for MIS," *Datamation,* 155–164 (July 1981).

J. D. Couger, "Evolution of business systems analysis techniques," *Computing Surveys* **5,** No. 3 (September 1973).

G. A. Gorry and M. S. Scott Morton, "A framework for management information systems," *Sloan Management Review* **12,** 55–70 (Fall 1971).

R. H. Hayes and R. L. Nolan, "What kind of corporate modeling functions best," *Harvard Business Review* **52,** No. 3, 102–112 (May–June 1974).

B. Hedberg and E. Mumford, "The design of computer systems: Man's vision of man as an integral part of the systems design process," in *Human Choice and Computers,* E. Mumford and H. Sackman (Editors), North-Holland, Amsterdam, The Netherlands (1975), pp. 31–59.

A. M. Jenkins and R. D. Johnson, "What the information analyst should know about body language," *MIS Quarterly* **1,** No. 3, 33–47 (September 1977).

W. R. King and D. I. Cleland, "The design of management information systems: An information analysis approach," *Management Science* **22,** 286–297 (November 1975).

K. London, *The People Side of Systems,* McGraw-Hill Book Company, Inc., New York (1976).

J. C. Miller, "Conceptual models and determining information requirements," *Proceedings of the Spring Joint Computer Conference* **25,** 609–620 (1964).

B. Shneiderman, *Software Psychology: Human Factors in Computer and Information Systems,* Winthrop Publishers, Inc., Cambridge, MA (1980).

The author is with the School of Management, University of Minnesota, 271 19th Avenue South, Minneapolis, MN 55455.

Reprint Order No. G321-5159.