MANAGEMENT SCIENCE
Vol. 22, No. 3, November 1975
Printed in U.S.A.

THE DESIGN OF MANAGEMENT INFORMATION SYSTEMS: AN INFORMATION ANALYSIS APPROACH*†

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This paper describes a methodology for management information systems design which employs a formalized framework for significantly involving manager-users in the design process. The process seeks to develop a system design on the basis of a criterion which considers both technical cost-benefit considerations and the manager's perception of the potential utility of the system. A key element of the methodology is the development of descriptive and normative system models which are based on the concept of a "linear responsibility chart." These models serve as the basis for the negotiated development of a consensus system model which defines the framework for the decision-oriented analysis of information requirement. The process of information analysis involves joint manager-analyst activities which are aimed at the explication of the implicit decision models which are used for decision making.

There is no dearth of literature on the process of designing management information systems (MIS). Any basic text in the area [1] provides a description of a series of phases for the design process. However, one crucial aspect of any MIS design process is not usually dealt with on anything but a "principles" [2] basis. That phase–the specification of the *information requirements* of managers–is frequently dealt with using subjectively-developed maxims which are often developed on the basis of debunking traditionally accepted principles. For instance, Ackoff [1] critiques a number of traditional "assumptions" of MIS design such as, "the manager needs the information he wants," and thereby develops some important principles of modern MIS design.

Despite the utility of MIS design principles and procedures such as those suggested by Ackoff, there is little in the way of an MIS design methodology which has both a theoretical basis and a "track record" of meeting the operational "information needs" of managers. This is illustrated by a report of the ACM Curriculum Committee on Computer Education for Management [3] which concludes that this aspect of the MIS design process is one requiring a set of skills unlike those usually possessed by systems analysts or programmers. To fill this critical void, they have proposed the development of curricula focused toward a new variety of analyst–the "information analyst," who

* Processed by Professor Charles H. Kriebel, Departmental Editor for Information Systems, and Associate Editor Gordon Davis; received August 30, 1972, revised May 21, 1974. This paper has been with the authors 3 months for revisions.

† This research was supported through Grant #NI-71-096 of the National Institute of Law Enforcement and Criminal Justice, Law Enforcement Assistance Administration, U.S. Department of Justice. The aid of research assistants Dundar Kocaoglu and Peter Smith and the cooperation of former Commissioner Frank N. Felicetta, Comissioner Thomas R. Blair and Captain Phillip Francis of the Buffalo New York Police Department is gratefully acknowledged.

[1] For instance see Murdick and Ross [15, Chapter 13].

[2] The reference to "principles" here is an analogy to the "principles approach to management." Such principles as, "One and only one boss for every subordinate," are no longer regarded as an adequate basis for the practice of management. See King and Cleland [11, Chapter 7].

works closely with system users to determine their information needs.[3]

There is considerable evidence to suggest that the lack of involvement of managers in the design process–in this crucial phase of determining information requirements as well as in other phases–has been a significant factor contributing to the failure of many MIS to perform as expected. For instance, a McKinsey and Co. report [4] reveals that "...many otherwise effective top managements are in trouble with their computer efforts because they have abdicted control to staff specialists." And Diebold [6] reports that "...technicians, not management, are setting goals for the computers."

Objective and Basic Premises

This study addresses itself to the development of a methodology for MIS design which focuses on the determination of the information requirements of managers in a formalized, yet participatory, fashion. The approach seeks to provide an objective framework for analyzing information requirements while at the same time significantly involving the managers, who will be the MIS users, in the design process.

In achieving this objective, the methodology operationalizes some theoretical and research results regarding the participation of managers. This is done in a decision-oriented framework which makes use of the model-based management-analyst teamwork concepts presented in King and Cleland [11]. The methodology is also built on some of the ideas of Ackoff [1].

This MIS design methodology has several important features which simultaneously enhance its value and potentially constrain the domain of its applicability.

First, it is *decision-oriented* to a degree which might preclude its use in the development of data processing or operational-level information systems such as those designed to perform billing, accounting or other repetitive operations. The contexts in which it has been developed and tested exclusively involve nonroutine activities and decisions.

Secondly, the methodology involves participation on the part of the managers who will use the MIS. It emphasizes this manager participation to such a great degree as to require the acceptance of a *broader definition of optimality* than that usually adopted by MIS designers. Of course, many approaches to MIS design involve management participation in specifying information needs and in reviewing the system development effort. However, this approach involves user participation in basic systems design decisions which are usually thought of as "technical" in nature. Thus, the methodology can produce systems which cannot be thought of as optimum in the technical sense.

In this regard, the approach is addressed to a broader variety of optimality which considers *both* technical cost-benefit considerations *and* the manager's perception of the potential utility of the system in enhancing his decision-making effectiveness. The essence of this broader view of optimality is the belief that a technically-optimum system which goes unused is inferior to a system which is technically inferior, but perceived to be useful by the organization's managers.

Such an optimality criterion is natural in the context in which this process was initially developed—strategic planning in a police department—because police departments, like many similar organizations, currently do little of their strategic planning on the basis of objective information provided by a MIS. Thus, a rationally-developed system which is based on sound theory has benefits that go far beyond those of the existing organizational "strategic planning information system." If such a system can

[3] See also Argyris [2] and Dyckman [7].

be developed in a fashion which ensures that it will be accepted and used, its overall value to the organization is much greater than that of a technically superior system which, in similar contexts, has relatively little real impact on decision making.

This broad concept of optimality is consistent with trends in current thinking in systems design,[4] but the prescribed degree of manager involvement in MIS design cannot be justified as optimum. Indeed, one might consider the design approach to be an experimental one aimed at investigating the operationalization of Churchman and Schainblatt's [4] manager-researcher "mutual understanding" and Mason and Mitroff's [13] "principles" regarding the needs of managers for information which suits their psychology and for methods of generating evidence that are geared to their problems.

The other basic premise on which the methodology is built has to do with the intrinsic interrelatedness between the MIS and the activities which it is to support. In the case of a strategic planning MIS, this interrelatedness suggests that the organization's processes for performing strategic planning and the supportive MIS form a total system. Thus, the MIS cannot be developed to serve a given strategic planning process any more than the planning effort can be designed to "fit" an already-developed MIS. The achievement of a systems design under the broader concept of optimality requires that the planning process and the MIS be jointly developed to best serve the overall needs of the organization.

Information Requirements Analysis

The information analysis design methodology is conceived of as a process involving a series of steps. As in most such processes, the sequencing of the steps is in terms of the initiation rather than in terms of the execution of each. Thus, step 1 *begins* before step 2, but because of the implicit feedback loops and interdependencies in the process, step 1 may not end prior to the end of step 2.

The various steps in the process are:

1. Identification of User Set and Interfacing Organizations
2. Identification of Decision Areas
3. Definition of Decision Areas
4. Development of a Descriptive Model of the System
5. Development of a Normative Model of the System
6. Development of a Consensus Model of the System
7. Decision Model Identification and Specification
8. Specification of Information Requirements

Each of these steps will be explained using elements of a police strategic planning MIS design process for illustration. In all cases, the illustrations are from a real-world situation, but they are not intended to portray comprehensively the police system in question.[5]

Identification of User Set and Interfacing Organizations

The "user set" for an MIS–the set consisting of those managers who are designated to be the primary users of the system's output–is in part specified by the stated objectives of the system. Such objectives must be clearly defined prior to embarking on an analysis

[4] For instance, see Churchman and Schainblatt [4], Huysmans [8], Mason and Mitroff [13], and Schultz and Sleven [16].

[5] See Law Enforcement Assistance Administration [12].

of information requirements. For instance, a system which has the objective of supporting corporate long-range planning will have a user set which is quite different than the set for a production control system. Indeed, the user set for a corporate-level control-oriented MIS may well differ from that for a corporate-level planning MIS.

In this MIS design process, the user set is initially defined by the analyst, using the statement of objectives for the MIS, organization charts, job descriptions and other documents, as guides. In the strategic planning MIS case, the system objectives reflect the recognition that past planning inadequacies are largely due to a lack of relevant information. Most of the information, or data, that is currently processed by the organization's information system is descriptive of the past history of the internal organizational subsystem. Most of it is outdated and inward directed. To be useful for strategic planning, such information must be prospective and focused toward those environmental and competitive elements of the organization that will most critically affect its future.

Because of this objective, this variety of MIS must consider external interfacing organizations as well as internal users. These organizations are defined in terms of specific informational inputs and outputs–i.e. those organizations with which information is communicated in support of, or as a result of, the functions which the MIS is to support.

The column headings in Table 2 show a list of users (by position level) and interfacing organizations for a police planning MIS. The listing shown there represents a "first pass" by the analyst, and it thereby emphasizes position levels (ranks) more than specific positions. Because of the intrinsic interrelationship of positions, interfacing organizations and decision areas, further refinement of this list would take place as subsequent steps are performed.

Identification of Decision Areas

The next step in the information analysis process involves the identification of decision areas. This step is initiated by the analyst on the basis of existing "theory" and refined by him through discussion with the appropriate managers who will be the users of the system.

Table 1 shows such a "decision inventory" related to the planning function of a police department. It represents one possible delineation of some of the critical decision areas involved in the planning process in any organization.

TABLE 1.

POLICY FORMATION — INTERNAL
POLICY FORMATION — EXTERNAL
DIRECTION OF OPERATIONS
ORGANIZING ACTIVITIES
BUDGET
TACTICAL PLANNING
COMMUNITY RELATIONS
NEW PROGRAMS
TRAINING
PERSONNEL SELECTION
ALLOCATION OF RESOURCES
RESEARCH
EXTERNAL COORDINATION
INTERNAL COORDINATION

Other categorizations could be used as well. In fact, during the process of developing such an inventory, the analyst will usually begin from a theoretical point of view based on his highly abstracted view of the organization and then proceed to revise his inventory based on discussions with executives and members of the user set. This process serves to provide a good theoretical foundation and to ensure that major omissions are avoided, while at the same time avoiding the problems of confusing terminology and overlapping decision areas.

Definition of Decision Areas

After decision areas have been identified, they must be specified in detail. The discussions held with executives and the members of the user set, as outlined in the previous step, will assist greatly in achieving the desired level of specificity. These discussions serve a secondary purpose as well—the obtaining of support and acceptance by the people on whom ultimate success will depend.

The process involved here is, therefore, much the same as that of the previous step except that the decision areas are broken into decision elements on the basis of their (1) homogeneity, (2) need for common informational input, or (3) performance by a single individual or unit. In all cases, these assessments must be made on rather loose grounds, since rigorous formal criteria are probably unwarranted at this preliminary definitional stage.

A definition of each decision area may be in process terms such as that shown in the row descriptions in Table 2 for the decision area "external policy formulation" for a police department. The process of formulating policies related to the police department's environment is described as consisting of a number of general steps ranging from the analysis of data reflecting various clientele groups to the implementation and control of policy decisions.

Development of a Descriptive Model of the System

The third phase of the MIS design process involves the utilization of the user set and decision areas to develop a descriptive model of the organizational and environmental systems which are relevant to the MIS. This is done in a two-dimensional format which is an adaptation and extension of the concept of a "linear responsibility chart" (LRC).[6] The LRC is a simple organizational model which was originally introduced to provide a more realistic description of the operation of organizations than does the traditional hierarchical chart. The method used to accomplish this is to describe authorities, responsibilities, and roles in a matrix form which relates positions and tasks through the use of coded symbols designating the specific roles to be played by each position in the accomplishment of each task.

Although the overall use of the LRC in this methodology is normative, this phase of its use is descriptive. Table 2 describes the existing external policy formulation processes in a police department. Similar models should be developed to describe existing organizational processes in each of the decision areas which the MIS is to support.

The entries in the chart represent a number of organizational characteristics with regard to the decision area:

(1) authority and responsibility relationships,

[6] See David I. Cleland and William R. King, *Systems Analysis and Project Management*, McGraw-Hill, 1968, pp. 193, 196–198.

(2) initiation characteristics,
(3) input-output characteristics.

The codes used to describe these characteristics for internal positions are
I–Initiation
E–Execution
A–Approval
C–Consultation
S–Supervision

Numbered subscripts on these role descriptors serve to identify the specific relationship.

For instance, the simplified macro-level chart of Table 2 shows on the first row that the analysis of routine complaints (E) is handled at the police captain level under the supervision of an inspector (S) with the police commissioner having approval authority (A). In performing this function, the captain has the consultation of the uniformed patrolmen (C_5, where the subscript #5 indicates with whom the consultation takes place). Another consultation takes place when the Deputy Commissioner consults with the Commissioner (C_4) at the approval stage.

TABLE 2. *Descriptive Model of External Policy-Making Process.*

	City Council #1	Mayor #2	Budget Director #3	Police Commissioner #4	Deputy Commissioner #5	Inspector #6	Captain #7	Uniformed Patrolman #8	Police Administrator #9	Other City Depts. #10	Board and Agencies #11	Federal Government #12
Analysis of routine complaints				A	C_4	S	E	C_5				
Observ. of field practices				A	S	E						
Crime analysis												
Court analysis												
Analysis of social problems												
New legislation				A	S	E						
Issue clarification–definition				A	S	E						
Selection of alternatives				A	E	C_3						
Obtaining relevant facts												
Analysis of facts												
Review		A		E						$2^{i,o}$		
Formulation				E	C							
Articulation				A	S_4	S	E					
Training for implementation					A	S	E					
Execution and control				A	S	E	C_4					

Various informational linkages with interfacing environmental organizations are also depicted in these charts. Table 3 shows only one such linkage–that involving "other city departments" who both provide input (*i*) to and receive output (*o*) from the mayor (#2) in his approval role.

The model depicted in Table 2 is an abstract description of the way the system actually operates with regard to the single planning area described as "formulating external policy." While descriptive models such as this are often developed by systems analysts to provide themselves with a basis for understanding the functioning of a system, the purpose for this descriptive model in this methodology is, in fact, prescriptive. However, the use of the model in this fashion first requires that a comparable normative model be developed.

Development of a Normative Model of the System

A descriptive model of the organizational and environmental system such as that provided by Table 2 and other associated charts is a useful "road map" for guiding informational analysis. It provides insights into "who does what," the interactions among organizational units and between internal and external units, the general nature of information required, the direction of information flow, and the manner in which information requirements are generated.

However, the use of a model of this variety as the sole basis for information systems design would represent an abrogation of the information analyst's proper role. Rather than creating an information system to serve an existing organizational system, he should attempt to influence the restructuring of the decision-making process so that the MIS may be oriented toward the support of a more nearly "optimal" process.

To do this, the analyst may call on the best of the knowledge and theory of management to construct a normative model of the organization which is consistent with, and comparable to, the descriptive one previously developed. For instance, a police department which is not already using a program budget structure can be stimulated and aided in developing one by the incorporation of such procedures into the normative model.

A comparable normative model for the "external policy formulative" area is shown in Table 3 using the same format as was used for the descriptive model of Table 2. It was developed by the analysts on the basis of existing theory as constrained by the unique characteristics of the organization in question.

However, just as it would be inappropriate for the analyst to design an MIS to suit the descriptive organizational model of Table 2, it would be unrealistic of him to focus solely on the normative model of Table 3. If he were to do so, he would either design a completely inappropriate MIS (as many feel analysts are wont to do in some organizations) or autocratically impose the requirement for an organizational redesign as a response to the MIS.

To meet the criterion of broad optimality based on improved effectiveness and usability, the designer must seek some consensus model which can serve as a realistic basis for systems design.

Development of a Consensus Model of the System

Although few organizations desiring an MIS would be willing to restructure their organization's authority and responsibility patterns and relationships to suit the needs of the MIS, it is generally recognized that procedural improvement is a valid by-product of MIS design. Therefore, organizations are normally willing to consider some elements of a normative organizational model such as Table 3 rather than to insist simply that the MIS solely service existing procedures, authorities, etc.

The development of a consensus model hinges on an objective comparison of a descriptive model such as that of Table 2 with a normative model such as that of Table

TABLE 3. *Normative Model of External Policy-Making Process.*

	City Council = 1	Mayor = 2	Budget Director = 3	Police Commissioner = 4	Deputy Commissioner = 5	Inspector = 6	Captain = 7	Uniformed Patrolman = 8	Police Administrator = 9	Other City Depts. = 10	Board and Agencies = 11	Federal Government = 12
Analysis of routine complaints				A	C_4	S	E	C_7		7^i	7^i	
Observ. of field practices				A	S	E	C_6					
Crime analysis				A	S	E	C_6			6^i	6^i	
Court analysis				A	E	C				5^i	5^i	5^i
Analysis of social problems				A	S	E	C_6			6^i	6^i	6^i
New Legislation				A	S	E	C_6			6^i	6^i	6^i
Issue clarification–definition				A	S	E	C_6					
Selection of alternatives				A	E	C_5						
Obtaining relevant facts				A	S	E	c_6	C_6		6^i	6^i	6^i
Analysis of facts				A	E	C_5						
Review	A	A		E						$4^{i,o}$	$4^{i,o}$	
Formulation				E	C							
Articulation		A	A	A	C_4	S	E			6^o	6^o	
Training for implementation					E	S	E					
Execution and Control	A	A		A	S	E	C_6			6^o	6^o	

3. This comparison and evaluation must be done by managers with the aid and advice of analysts.

One possible medium for this process which has been used successfully by the authors is that of a "participative executive development program." The program involved the MIS user as "students" and the MIS analysts as "teachers." The normative model was developed and discussed in lecture-discussion sessions. After it had been communicated fully, workshops were used to facilitate the detailed evaluation and comparison of the descriptive and normative models. Recommendations emanating from the workshops were reviewed by top management, and those which were approved were incorporated into a consensus model of the system.

A consensus model of this variety provides the basic framework for analysis of both formal and informal information requirements. It identifies specific involvements of users in each element of each decision area. Further, it indicates the direction of the information flow in each phase–both within and outside the organizational system.

Such a model can therefore serve a variety of functions. It is a general plan for an MIS. Further, it is a prescriptive model for modified organizational processes which will be supported by the MIS. However, for purposes of this discussion, the primary value of the consensus model is as a guide to the information analysis which is an integral part of data base design.

Decision Model Identification and Specification

Once the framework provided by the consensus systems model is developed, the

analyst can begin to identify the specific "decision models" and criteria which are used to perform the activities specified in each element of the chart. For instance, each "Approval" activity can be detailed in terms of the criteria applied to the approval decision, and each "Execution" activity will need to have a model of the execution activity specified. In such a case, the model or conceptual framework which the manager uses to arrive at a decision can be specified through a process of manager-analyst interaction such as that described in King and Cleland [11].

The term "model" as used in this context is a broad interpretation of the usual usage. It includes not only sophisticated mathematical models, but also simple descriptive models and even the "mental models" which are a part of every decision-making process. Such models are difficult to assess in objective terms, but the necessity for doing so in MIS design has become clear.

To illustrate how such a "mental model" can be specified, consider a hypothetical portion of a discussion between a manager who makes hiring decisions and an analyst who is trying to help him objectively formulate his decision model.

Analyst: "What is the most important factor that you use to select the best man for the job?"

Manager: "His aptitude test scores. It is critical that we get someone with the aptitude for the job."

Analyst: "Is that all that you need?"

Manager: "Oh no, job experience is important too."

Analyst: "What if you had a man with high aptitude scores, but no experience and another with experience and modest scores; which would you choose?"

Manager: "The experienced one, if we had good evidence that his experience had been meaningful and that he had really performed well."

The discussion would continue much beyond this, but this brief portion demonstrates how a mental model may be made objective. In three questions, the analyst has begun to construct a model which relates "Job Success" to two predictor elements--"Aptitude" and "Experience." Further, he has begun (through the third question) to get some rough "priority weights" among the predictor elements.

In some decision areas, the end product of such a discussion might well be an objective model such as

$$y = a_1 x_1 + a_2 x_2 + a_3 x_3 + \ldots + a_n x_n + b \tag{1}$$

where y is an indicator of job success such as a performance rating, the x's are predictors such as "aptitude test score" and "years of experience" and the a's are "relative importance weights" which are determined subjectively by the manager. [7] Of course, in many areas, no model as specific as this one will be feasible. The remainder of the process to be described recognizes this, and allows for both formal and informal decision models.

Determination of Information Requirements

The final step in the process is the determination of information requirements from

[7] Alternately, if data are available, such weights may be statistically determined. See King [9].

the consensus model of the system and the specific "decision models" which have been explicated for each of the entries in the chart representing the consensus model. These decision models serve to specify specific information requirements and the consensus systems model prescribes the linkages and relationships of these elements of information.

If, for example, an "Approval" activity is indicated in the consensus model, it would have been detailed in the previous step in terms of the specific factors and criteria which need be considered in determining whether approval is to be given–e.g. the specific levels of these factors which need be achieved for approval to be granted.

To illustrate, suppose that an "Approval" activity associated with a hiring decision is under examination. The manager might have explained his "model" for the "Approval" activity as:

(1) First, check to see that all company hiring policies have been followed.

(2) Then, check to see that no one already in the organization desires to fill the job.

(3) Then, check to see if the candidate helps us to fulfill our objectives with regard to minority group hiring, and, if not, to ensure that no equally good candidates are available who will help us to achieve them.

These criteria specify a rather specific set of information requirements:

(1) hiring policies,

(2) data on candidate and hiring procedure relevant to each hiring policy,

(3) comparable data on existing personnel,

(4) data on job transfer desires of existing personnel,

(5) minority group status of candidate.

(6) data on other candidates.

Of course, in order that these represent operational information requirements, these elements would need to be detailed much further. However, once specifications such as these have been made, the process of detailing them is a straightforward one.

Alternately, suppose that an "Execution" activity has been explicated in the form of the formal model of (1). Such a model specifies information requirements in a number of ways. First, the performance measure, y, represents an information element which must be provided by the MIS. Although such data will not be available for candidates, historical data will be necessary to judge the validity of the model as it continues to be used. Secondly, the predictor variables (the x's) are input data for the decision, as are the "weights" (the a's).

Thus, such a model would provide a list of information requirements of the form:

(1) historical data on performance ratings of personnel,

(2) applicant aptitude test score,

(3) applicant experience in years,

(4) minority group membership,

(5) relative importance weight for aptitude test score,

(6) relative importance weight for experience,

⋮

etc.

If more sophisticated models are developed, other information requirements may also be determined. For instance, the solution to an optimization model may itself entail information specifications. [8]

[8] See King and Cleland [11].

Conclusion

The MIS design process described here directly produces both a set of information specifications and an overall general systems design in the form of the consensus systems model. It represents a structured method for incorporating managers into those aspects of the design process which are typically left to technical analysts.

In doing this, it provides the capability of developing systems that are, in part, designed by the people who best understand the job that the systems are to do–the user managers–and it permits the development of systems which incorporate many of the informal indicators and practices that managers commonly develop and use outside of the domain of formalized information systems. This latter capability is inherent in both the systems model phase, which begins from a descriptive model, and the information requirements phase, in which managers are asked to explicate their reasoning with regard to specific functions and decisions.

Since the methodology is based on the concept that the system should be designed by those who best know the "business" and who will be users of the system, it is addressed to a broad variety of optimality which encompasses both technical cost-benefit concerns and the user's perception of the usefulness of the system. Thus, the design process involves not only managerial "input" and review, but managerial design decision making.

This approach is consistent with recent research and conceptual results in systems design as well as with many existing systems design practices. For instance, the consensus model can provide the basis for traditional input-output identification of information flows as well as providing the basis for the more sophisticated decision model information analysis.

Perhaps more importantly, the approach provides an orderly and systematic basis for participatory organizational change as well as for MIS design. The interrelationships of various organizational dimensions such as management systems and procedures, information systems, organizational structure and management practices is becoming increasingly apparent.[9] The difficulties in operationalizing comprehensive changes in these myriad dimensions are severe however. With this approach, such changes are structured by managers rather than by analysts. The greater understanding of the need for change and of the value of specific changes which this process engenders in managers may well be its greatest asset.

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[Footnotes]

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