MANAGEMENT AND INFORMATION SYSTEMS*)

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1 Introduction

It is my aim to discuss in this paper two major issues regarding the use of computers as an aid to management. First, I shall try to explain in more detail my standpoint that the roots for any information system can only be found in management and organization theory. Secondly I shall discuss the way in which computers can be used to automate several parts of these systems.

As a consequence, it can by no means be my intention to present you with a guide for the development of a management information system. A generally useful recipe calls for such a great experience that virtually nobody is able to present it at the moment, if a complete management information system ever has been designed.

In the meantime, it will be worthwhile to investigate the development in major areas from which contributions to MIS-design can be expected.

2 Management- and Organization theory

Information Systems

Whenever I use the word „information system" it represents a system to collect, record, process, and distribute information in any organization. A wide variety of techniques is available for use in information systems. The functions of these systems, however, have not basically changed in the course of time.

Today, like before, we emphasize:

1 The Control function,

2 The Accounting function.

As we focus our attention on the directive role of management we shall distinguish three major sub-functions within the control function.

1.1 The Implementation function; the system supports the information exchange during the implementation, including the instruction of the people and the instruction compliance. (A qualitative measurement regarding the correct use of instructions)

1.2 The Performance function; including the development of standards, the measurement of performance and possibly a two-way corrective action.

The former is based on a comparison of standard and performance, the latter is the result of the qualitative judgments made during the implementation. In addition the standards and instructions themselves may be adjusted.

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1.3 The Planning function; here generally two important types are recognized:

1.3.1 Planning based on a mere extrapolation of the historical data of the organization.

1.3.2 Planning based on a more sophisticated analysis of a wider range of data, including complex statistical and mathematical routines. These data do not only represent the organization itself but also give information on the environment - in the broadest sense - in which the organization operates. (Buying and selling markets, government regulations, the national economy etc.)
This type of planning is often referred to as Strategic Planning.

Decision making

Relating our observations of management to the functions of information systems, it becomes clear that what managers primarily do, is making decisions. These decisions are based on the information on hand. A feedback loop, being a procedural part of the organization, finally tells management whether their implementation decisions, their performance decisions, and their planning decisions were correct or not. Virtually, this procedure offers the possibility of an adaptation of management to changes in the situation. (A learning process)

All this perfectly fits into the picture of a classical management- and organization theory, in which we concentrate on:

1 Specialization among organizational units and specialization among individuals. (Organization Structure)
2 Authority, flowing from the top to the bottom of the organization. (i.e. Unity of Command)
3 Coördination as the necessary counterpart of specialization.
4 Control of delegated powers, as the necessary counterpart of authority.
5 The distinction between line and staff activities.

However, with a growing complexity of organizations and a growing complexity of the environment in which they operate, it becomes increasingly difficult to make adequate decisions and to do so in good time. Moreover, there exists an increasing time delay before the consequences of a decision can be perceived. Probably these facts too have been important reasons to emphasize the research of decision making as part of management and organization theory.

Economic Man

Economics have been described as a science of choice. Although incomplete and so partially incorrect, this discription indicates that the decision making process plays an important role in economics. I shall therefore make some further investigations in this field. Economic man has always been a central premise to economic theory. As a consequence, a large part of the scientific work done in this area so far has been essentially normative in character. The theory develops rules to tell the decision maker how he *should* make the class of decisions for which the theory is appropriate.

Economic man is presumed to have two important qualities. He is (1) completely informed and (2) maximizing values, or more accurately, maximizing utility. We usually state that economic man is rational, to indicate that he knows all the alternatives open to choice and all the consequences of each alternative. With this knowledge it is possible to make a „preference ordering" so that he is able to maximize utility through his choice. It will be readily understood that the decision making rules derived from such a set of premises only have a very limited utility.

More recent developments in economic theory are directed towards the study of probably more feasible variations in premises. The elements of risk and uncertainty in decision making are introduced. Decision making under risk implies that a choice should be made in such a way as to maximize *expected* utility. For the rest the theory still presumes that all of the alternatives are known, and that a preference ordering is possible because the probability of all the consequences is known. Game theory is an example of a normative theory for decision making under risk.

With the introduction of uncertainty, again, the individual is presumed to know all the alternatives. As in decision making under risk he also knows all the consequences which may result from each alternative. But uncertainty is in the picture because the probabilities of the outcomes are unknown, perhaps the outcomes themselves are even meaningless. Several normative theories have been founded on these premises. But it is doubtful whether their suggestions are very useful. One suggestion is that the decision maker should maximin utility, that is to say that he should consider all the alternatives and all the possible outcomes and finally choose that alternative whose worst outcome has the highest utility. Another theory suggests the minimax of regret. Regret being represented by the difference in utility payoffs between possible alternatives and consequences. Both rules result in a highly conservative behaviour. Actual behaviour will almost certainly be different.

Apparently the decision rules taken from the normative economic theory can by no means guide decision making in a variety of practical situations. At least a number of organization scientists believe that quite a different approach is needed, which focuses on the development of a descriptive theory of decision making. The set of premises underlying each of the possibilities discussed so far does not fit in such a descriptive theory, which primarily aims at the explanation of actual behaviour in decision making.

Administrative Man

In 1947 Herbert Simon introduced administrative man in contrast with economic man. Administrative man, however, is not the representation of a set of premises but a slowly developing descriptive model of decision making in administrative organizations. Since the introduction of the first outlines of his approach in „Administrative Behavior", he has contributed more than anyone else to the development of a descriptive theory of decision making. I may refer to the small bibliography inserted at the end of this paper.

Simon, and a number of other management and organization scientists

leaning heavily on his ideas, emphasize three major qualities of administrative man. There is a clear distinction to be made between *fact and value* in decision making. Questions of fact are to be regarded as questions of what is, whereas questions of value are questions of what ought to be. Questions of fact can in principle be answered by research. Questions of value, however, have no empirical answers. There exists no scientific method to determine the ultimate values.

This distinction is equally important to both normative and descriptive theory. The statement made before that a normative theory indicates how a decision should be made has to be completed with another statement indicating that such a decision can only be made by taking the values of the decision maker into account. Any decision not only involves a factual judgment - a statement about the future observable world around us and the way it operates - but also a value judgment - an imperative selection of one of the alternative future conditions of the observable world above all others -. This, however, has not been explicit in the normative theories discussed earlier.

There exist important *limits on „objective rationality"*. In his early studies Simon already rejects the idea that an individual decision maker really knows all the alternatives open to choice. Only a very limited number of behaviour alternatives is within the human range of vision. He also rejects the possibility that the individual can have an insight into all the consequences related to each alternative. Since these consequences are in fact statements about the future observable world, our imagination has to support experience in making the final value judgment. Moreover values are imperfectly anticipated.

Finally, there are severe limits on objective rationality inside the organization. Two important classes of mechanisms influence organizational decision making. The first one focuses on the individual to make it possible that he autonomously makes the most useful decision for the organization. We mention the use of organizational loyalties, the notion of efficiency and the use of training. The second class of mechanisms emphasizes the means to impose on the individual or group decisions that have been made elsewhere in the organization. The influence here is related to authority, as well as advisory and informative services.

Continual research convinced Simon that not only objective rationality has to be rejected but that at the same time the maximizing premise also proved to be inadequate. He suggests that the *maximizing* premise be replaced by a description of actual behaviour which he calls *satisficing*. There are two important differences between these concepts. First, a behaviour directed towards the maximization of utility is based on the objective rationality discussed before. Only with these premises is it possible to maximize. In a satisficing behaviour, however, the decision maker is assumed to begin by searching for possible alternatives and for information related with the consequences of each of the alternatives. In this process he will select the first alternative he encounters which meets his minimum standard of satisfaction in relation to the value judgments he made. Secondly, in the theories which predict maximization of utility it is usually assumed that utility

remains constant in the course of time. As a consequence of past experience, in the satisficing behaviour of administrative man the minimum standard of satisfaction, however, will regularly be modified. The concept of satisficing behaviour is evidently related to the concept of the level of aspiration in psychology. Moreover, next to the individual the group plays an important role in organizational decision making. The maximization of group utility represents a serious theoretical difficulty. It is much easier to cope with the satisficing concept in group decision making.

The most important conclusion we can draw from the theoretical statements and the related research we discussed, is that apparently the human intellective capacities are limited in relation to the complexities of the problems that both individuals and organizations face. *Bounded rationality* captures the main features of a decision, but certainly not all its complexities. In decision making administrative man concentrates on:

1 The search for alternatives of action and the information related with the consequences of the alternatives.
2 The satisfaction to obtain from successively discovered alternatives in relation to the value judgments made, until an acceptable level of satisfaction is reached.

Considering the use of computerized management information systems, these two conclusions should be kept in mind.

Search and problem solving

The search procedure we emphasized before is not only part of the descriptive theory of administrative decision making but also a central theme in the theory of problem solving. In the newest approach to problem solving the thinker is regarded as an information processing system. Several attempts have been made to simulate the human problem solving process with a computer in order to prove the hypotheses derived from that approach. The use of simulation in this case has considerable advantages. Not only has the theory of problem solving to be expressed very precisely, it is also possible to include many more variables in the model than can be handled with the more familiar methods. Finally, the consequences of changes in even complex models may be determined quickly and rigorously.

Meanwhile a distinction has to be made between algorithmic and heuristic processes in problem solving. An algorithm is a problem solving process which guaranties a solution within a finite number of steps. That is to say it does so if the problem has a solution. A heuristic is a process which aids in the solution of a problem, but offers no guarantee of finding any. One heuristic for example is that of „working backwards". Begin with the result you wish to obtain and then work backwards step by step towards that which is given. Another example is „the use of analogy". Look for an analogous situation you have successfully dealt with in the past. Use the same solution rules as you did before.

The decision tree or maze provides a useful abstraction of problem solving activity. The maze represents the set of all the possible choices to be made in attempting to solve a problem. Some subsets of the maze are distinguished

from others by giving rewards (solution). In fact, with the aid of a heuristic, we select a path through the maze, hoping the path will lead to an acceptable solution. Mostly a heuristic is specific for a certain kind of problem.
One of the first programs developed to simulate human problem solving was the Logic Theorist, designed by Newell, Shaw and Simon. The authors started the design of the program by attempting to identify the heuristics used in the discovery of proofs for statements in elementary symbolic logic. This was done with a technique in which subjects engaged in proving theorems of symbolic logic were asked to think aloud. The heuristics so discovered from the protocols gave an indication of the way in which a problem solver searches his path in the maze. Next to these heuristics all the axioms from the Principia Mathematica of Whitehead and Russel were admitted into the program. The computer was then asked to prove the first fifty-two theorems in Chapter two of the Principia in the sequence in which they appear there. Each theorem that was proved was stored in memory and available for the construction of proofs of subsequent theorems. The program succeeded in proving 73% of the theorems. However, presentation of the theorems in a different order gave a considerably lower percentage of proved theorems.

There exists an apparent similarity between the search for alternatives by administrative man as a part of decision making and the individual problem solving process with the assistance of heuristics. This, and other research on problem solving and decision making, presents us with a third important conclusion that is very useful when we want to discuss management information systems.

3 Decisions occur in sequences. The availability of relevant information for later decisions depends to a large extent on the nature and the consequences of the decisions taken before. (Generally stated: learning counts)

3 Relating decision making and information systems

We take it for granted that a useful management information system has to support the decision making process as we discussed it before. As our conclusions show, the search for alternatives of action and the consequences related with each of the alternatives are activities central in decision making. Yet it has seemed to be impossible so far to design information systems that will support the search for alternatives of action. The aid of an information system in the search for the consequences of each of the discovered alternatives, however, is very likely to be profitable. The properties by which a digital computer distinguishes itself from the human being enlarges the area of possible applications in supporting decision making considerably.

Going back to the functions of information systems it is evident that the systems in which the implementation and performance functions are emphasized are primarily directed towards a selective dissemination of information on the running production process. A budget system built up in accordance with the organization structure and the related competences and

responsibilities, will be a helpful basis for the development of information systems performing these functions. The number and the nature of the decisions to be taken, however, is very much restricted by (1) the technology of the production, (2) the set of instructions and (3) the set of standards. The adjustment of the sets of instructions and standards is equally restricted by the technology of production. The planning function, however, especially on the highest level in an organization where strategic planning is in focus, will be very well supported by any information system that enables the search for the consequences of each of the alternatives considered. It is obvious that on every level within an organization behaviour alternatives may be evaluated. Nevertheless, the complexities of the relations that play a prevailing role in strategic planning, the number of variables, and the calculations that are to be performed make top level information systems, above other ones, fit for the application of digital computers.

The use of models

The information systems we have in mind may be defined as models. A model in this case is a representation of a part of reality, further to be specified with the aid of variables and their relations. The choice of the models to be used and the relations to be incorporated in each of the models depend on the nature of the organization concerned and the environment in which it operates.

For the managers of an enterprise, for instance, the effect of changes in several variables, such as sales, inventory level or maintenance program, on profit and loss is crucial for their judgment of the decisions to be taken. They will try to set up a profit and loss model in which they incorporate primarily the main variables that have in their mutual dependence a significant influence on profit and loss. As in the dissemination systems, the budget will again be a valuable starting point. This „rough" set up of a profit and loss model may later on be refined with the construction of a number of related models. I mention Inventory Models, Transport Models, Maintenance Models and Production Planning Models in a make-to-order industry etc. All these models, which are in part mutually dependent, can be developed separately. Finally, they support the improvement of the profit and loss model.

Although a profit and loss model seems to be a very attractive instrument for top management, it has to be taken into account that the development of this instrument deserves a lot more attention for information-systems design of the managers themselves than they have given hitherto. It is even recommended that management makes the initial start of the design, because the main elements of the system have to support corporate strategy. Only in this way will the managers be fully aware of the inevitable relation between their own value judgments and the information systems that have to support their factual judgments.

It is evident we recommend a top to bottom approach in the design of management information systems, developed to support strategic planning. As a consequence, a few other questions deserve attention. What should be

the nature of the model designed? We distinguish between optimizing and simulation models. For optimizing models it is essential that they encompass rules (algorithms or heuristics) to ensure such variations in the variables so that successive solutions of the model converge to the optimum. Besides, into optimizing models all the variables and all the relations are incorporated. The question whether, in fact, all variables are discovered remains un-answered. Taking into account the problem solving procedures we discussed before, it is even doubtful whether all the alternatives of action will be discovered. In a simulation model, on the contrary these variations in the variables are not part of the model and only those variables that have proved to be the most relevant are incorporated. Yet, the use of only the most relevant variables and their relations at the same time urges the designer to develop rather simple procedures with which it is possible to alter the logic of the model. In doing so, however, we soon encounter the inflexibility of our information systems. The description of all the aspects of the application taken into account, and the clear distinction between data and program, often makes it necessary to redefine both when changes occur. Even with the use of high level languages such as FORTRAN or COBOL, and the use of a variable record length, this is costly. The development of application specific languages such as CODIL, COntext Dependent Information Language, in which all statements contain explicit structural information, while all commands are implied, favours the application of simulation models. As far as I know this type of language is not yet available for operational use. (See REYNOLDS, 1971) Moreover, the variables used in both models can be of the deterministic or the probability type. Finally, it is not only possible to make use of algorithms in constructing models, but heuristics may be used as well.

In this paper we primarily emphasize the SUPPORT of a decision making process with models. The use of relevant heuristics remains with the manager. Of course, it is possible to allow the use of heuristics to be discovered in the construction of the model. For the time being, there will nevertheless be many pitfalls before a suitable model of a more conventional type (non heuristic) is in operation. So four major models remain in focus. Optimizing or simulation models, both with deterministic or stochastic[1]) variables.

The final information system that supports decision making should embrace a number of important attributes.

1 It uses a simple model. In order to gain a complete acceptance of the model by management the logic should be transparent.
2 The system provides fast response facilities. If the manager has to wait for hours - or days - before the system provides him with an answer no real support of the creative process of human problem solving is experienced. Only a direct dialogue between man and computer makes it possible to take full advantage of creativity and initiative of man and the accuracy, reliability and speed of a computer.

[1]) i.e. probability-type.

3 It is a conversational system. So it will not only be possible to alter the values of the variables in question, but there also exist facilities to change the logic of the model, if desired.
4 The system provides a multiple point accessibility.

At this point in the discussion we present two theses:
1 The most useful model to support decision making in strategic planning is a simulation model.

There are several reasons for this choice.
* It is relatively easy to understand the logic of a simulation model. Because of this clearness the model will easily gain acceptance.
* As compared to an optimizing model the number of relations is very much restricted. The calculations are performed fast. Alternative calculations can really be made; time is not prohibitive.
* Adjustment of the model itself to changes in the organization or the environment is possible in a comparatively simple way.
* The models can be developed in a relatively short time.
* Design and operation costs will be considerably lower than with an optimizing model.
* With a relatively simple conversational language available there exists a wide range of applications in the organization in question, without time-consuming and difficult instruction.
* It is possible to enclose variables of the deterministic and probability type in the model.

We would be incomplete in our presentation if we did not mention the most difficult aspect of the use of simulation models. How should the validation of the whole model be performed? The most common means, of course, is an empirical validation. A strategic planning model, however, presents something new, yet to come into being. Of course, a validation is possible by comparing actual information on the subject with a simulated output based on historical data. If, however, such a procedure is not possible the most reasonable validation lies in common sense judgment and in the future results. Yet, in strategic planning this could be a dangerous approach. The validation possibilities should have considerable weight when taking the decision to use simulation models.

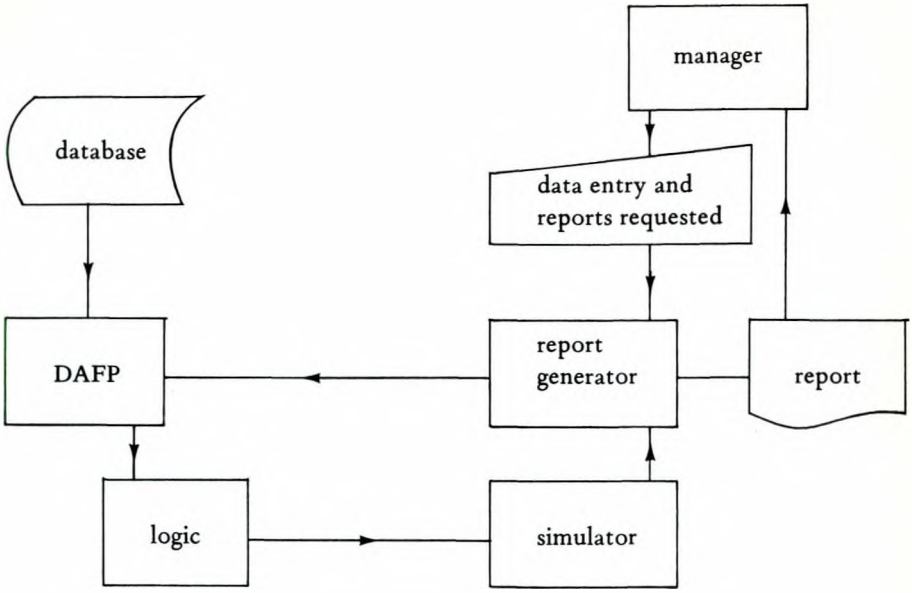
2 The most useful hardware to support decision making in strategic planning provides on-line real time facilities.
* An on-line real time computer provides the fast responses that really support decision making. Immediate action is made possible.
* The conversational aspects of the information system, which means that changes both in the variables and the logic of the model must be possible, are fully taken into account.
* A multiple point accessibility is guaranteed.

Elements in simulation systems

Apart from the computer hardware and software three main elements can be distinguished in the type of information systems we discussed.

1 The data base. This data base will be separated into two parts. In the first part all the data concerning the organization in question are collected. Directives for data collection are provided by the simulation model. Data on all the variables enclosed have to be made available. It is certainly not very easy to make this part of the data base operational. Not only will the range of historical data often not be available in a machine legible form, but especially data standardization will also be a time consuming activity. The various sub-models all have to produce compatible outputs. Once this standardization task is started it will be discovered that, if we work with a number of departments and if an even larger number of people are collecting data, deviations in the data definition easily slip into the system. Simulation results will soon be seriously distorted by incorrect data. The second part of the data base provides - in relation to the models used - information on the environment in which the organization operates. Not only does it represent the buying and selling markets but also data on government regulations, crucial variables in the development of the national economy etc.
2 The models. Virtually, this is a file of equations representing in their mutual relations the logic of the various models tied together.
3 The simulation program. This program has two functions. First, it performs data analysis and, based on that analysis, a forecast of future values of the variables on hand. Secondly, with the forecasts, the values specified by management, and the logic of the model, a simulation will be performed and reports are to be generated.

Especially with a growing future use of strategic planning models in sight it is to be recommended to examine the possibilities of making at least part of the simulation program applicable in general. To perform data analysis and forecasting the simulation program needs a variety of mathematical and statistical routines, such as correlation calculations, multiple regression analysis, moving average calculations, calculations of seasonal corrections, etc. With an ever wider range of routines using largely acceptable data entry formats, it is possible to create a general data analysis and forecasting program, DAFP. It should be kept in mind, however, that it is not really in the realm of the manager to make a judgment about the analysis and forecasting techniques to be used in the information system. He approaches the system from another angle. It should be possible for him to select the reports he wants to be generated. The reports requested define the simulations to be performed. So when the statement defining the reports to be printed is presented to the computer the proper analysis and forecasting programs automatically should go into operation on the specified data in the data bank. In the same way the equations to be calculated are selected automatically and the simulation is performed with the forecasting values and the values specified by management. The final results are presented in a prespecified lay out.



Simulation system to support strategis planning

Except for the general Data Analysis and Forecasting Program (DAFP) it is very difficult to find other areas in which it is possible to define activities that can be generalized. In my opinion the only possible general element left is the PROCEDURE. Starting with some simple conversational statement it links the data entered by management, the DAFP, the logic in question and the pre-specified reports to be generated. I do not know if a supervisory program of this kind has been designed so far. Schematically the procedure discussed can be drawn as is shown in the chart.

It will be clear that in most applications the design of a DAFP requires a prohibitive amount of time. Evidently here is a market for „software houses" specializing in the use of simulation models.

I come to the end of my exploration in decision making and computer assistance. I hope that, at least partially, I convinced you that knowledge of and insight in management and organization theories are basic requirements for the design of any information system. The type of design I discussed can only serve as an example. However, it seems evident that the development of a general DAFP and if required, a supervisory program, will largely facilitate the use of strategic planning models of the simulation type.

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