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On the Use of Dynamic Models in Management Information Systems

The concept of information system has long been circulated among those who speak of the utilization of the electronic computer. An information system always means a system for automatic data processing. The large application of computers in the economy has however required the consideration of a special type of information system, namely the management information system. That is why, before making any other considerations, one must define more accurately the concept of management. In the following, we shall state a definition with a large response, by involving to the attributes of forecast, control and organization. This means that to manage means to foresee, to control, to adjust and to organize. The concept is valid irrespective of the object managed, which may be a technological process, the production of a plant or a macroeconomic system. The important fact is that the management system should ensure the exercising of the attributes of management. As long as the managed object was simple, all attributes could be exercised by a single decision-maker. As the managed object became more complicated, one had to resort more frequently to task delegation. As the volume of necessary data for the exercising of an attribute has become bigger, the attribute was exercised more heavily. Therefore, the need of mechanization has appeared, mechanography for simplifying control or the operations research models for ensuring forecast and organization. The appearance of the computer allowed, in addition the simultaneous treatment of several attributes, starting with an emphase on control. The first attempts to achieve a management information system were based on the exercising of the attributes of forecast and control.

Just as in their evolution the computing equipment covered several generations, management information systems have also gone through several generations. In the first generation the information system achieved a recording, just as the mechanographic systems used to do — for the deci-

sion-maker to see "what is happening" and it used simple algorithms with which simple planning models were solved. A typical example is the algorithm for solving linear programming models. Later on, other algorithms also appeared, developed on the basis of euristic models, which used experience and common sense rather than an elaborate mathematical theory.

All these algorithms — mathematical or euristic — achieved, the last analysis, a complicated handling of data stored into the storage devices of the computing configuration. The computer allowed the rapid handling of a big volume of data. When the volume increased, special problems arose in connection with the organization of these data and this is how the concept of data base appeared.

The third generation of information systems raised even more difficult problems. It was thus claimed that the managed object should be considered as a whole, that is, for example — in the case of information systems for enterprise management — all the functions of the enterprise should be considered (production, commercial, research-development, financial-bookkeeping, personnel). It was in this way that they have come to the concept of an integrated system was formulated. Then, a developed cybernetic conception has appeared which distinguishes two levels, necessary and sufficient for carrying out the attributes of management. Obviously, the list of improvements may be continued if we refer to the spectacular achievements linked with the software of the modern computers. However, it was obvious from the very beginning that the mathematical model provided by operations research or by any other branch of applied mathematics was more necessary than a euristic model. It was demonstrated for example, that linear programming was not sufficient in all cases and that nonlinear programming might provide something in addition. It was also demonstrated that nonlinear programming was equivalent to optimal control and that the very refined techniques specific for, characteristic of this field can be successfully used for decision-making in management when the managed object was a production system or an economic system in general. We shall dwell on this very fact.

First, let us see what offers classical linear programming, defined as the analysis of problems in which a linear function of several variables must be maximized or minimized when these variables are subjected to constraints, generally in the form of linear inequalities. Such problems occur, for example, in seeking the allocation of limited resources for achieving a desired objective (cost or profit). These problems are characterized by a large number of solutions which satisfy the imposed constraints. The choice of a certain solution depends on the objective chosen. Any linear programming problem, specified as above, can be solved with a few algorithms or mathematical methods. The best known algorithm in this case is the simplex algorithm, materialised for each computer in a parametricized programme deck.

A plan elaborated with such a model, however, does not take into account the evolution in time of the managed object, or, planning means the pre-establishment of certain indices. Obviously, this disadvantage may be eliminated by divining the planning horizon into periods and by carrying out optimization several times. But, it is not sure that the global optimum is obtained in this way and thus, the need is felt to include the time factor

into the model, namely to elaborate a dynamic model. These models grasp the behaviour in time of the managed object, that is their dynamics, or, in other words, they describe the trajectory of the managed object, namely the very development unfolding of the plan.

To elaborate dynamic models one applies to the concepts of state and control from the theory of systems. To elaborate a dynamic model means to write the state equations of the managed object. A simple example of a state equation for a production system is the following: the production stock of today is equal to the stock of yesterday to which is added what was produced from yesterday until today and is subtracted what was delivered from yesterday until today. If all the production intermediate unfinished stocks for all jobs are taken into account, a series of equations in obtained which altogether represents the vectorial state equation of the production process. If to these equations are added the constraints imposed by machine capacity, by the succession of operations, by delivery and constraints of another nature, a dynamic model is obtained. The problem of classical linear programming can thus be replaced by a dynamic linear programming problem characterized by a new type of constraint, namely the dynamics of the managed object which describes production flow at various moments. The state equation describes this flow showing, for example, how much should be produced at specific moments to ensure the carrying out of certain quantities imposed by strategical planning.

Formulated as such, the problem of planning or of efficient production scheduling can be treated more rationally. The mathematical problem, however, is more complicated. The computer is more strained as the size of the problem increases considerably. In fact, the solving of a dynamic linear programming problem involves means solving of several problems of static linear programming. Research in this field is trying to solve this very problem. Algorithms are sought, namely methods which should avoid a standard treatment involving techniques other than the classical ones.

The existence of a dynamic model is, however, useful not only for the correct formulation of a forecast, of a plan or programme but also for checking and control. In most management information systems, checking means measuring of indices and drawing up of reports showing the results at a given moment, eventually the deviations from the planned figures. It is natural, however, to wish-on the basis of these deviations-to obtain a clue about a correction decision, that is to annul this deviation. Something like that can be done with an algorithm which should process the deviation. Such an algorithm can be developed by investigating the dynamics of the system.

Finally, the attribute of organization — which the classical information systems have not approached so far — can be also exercised by means of a dynamic model. This time, the dynamic model is used for simulation. As usual, by simulation we mean experimenting on the model. In fact, the model is a representation of the connections existing between the elements of the management system. These connections reflect a certain existing mode of organization. By modifying these connections, we can imagine another mode of organization having a modified model. It is thus obvious that through

simulation of various modes of organization by adequately modifying the model, we can see "what happens if". The advantage is clear: without changing the real system we can anticipate the effects of the changes. An extremely efficient technique for developing such models — with which we should thus simulate the behaviour of an economic unit, of a territory and even of the national economy- is known under the name of "industrial dynamics". This technique was presented in several papers published in this review. It should be said now that the use of such models is imperatively necessary for a developed information system with which the attribute of organization should be exercised. They allow to set the trajectories of the system in various previsible situations, trajectories which in most cases are counterintuitive, namely they do not develop in accordance with expectations dictated by simple reasonings of common sense. This is only natural. The production systems are complex. Their development is dictated by a big number of factors, some of them powerfully influenced by the complex behaviour of human decision-makers.

It is worth dwelling on this fact. Decisions in the production systems are made by people and formulated in a natural language, strongly affected by ambiguity, a fact which allows special flexibility in comparison with any other artificial language. Moreover, in contradistinction to the technical systems, for exercising the attribute of checking, the measuring of the results is done by interrogating some people. They again resort to the natural language. A reporting of the type "the results are better" is extremely rich in content, in spite of the lack of figures. A foremen reporting this synthetizes an experience no other way of expression can concentrate.

The lack of precision is a reality which sometimes far from being an impediment tends to be a blessing.

Decision-making in uncertainity is characteristic for man and his environment and it should be realistically considered in the designing of any management system. That is why it is necessary to take into consideration uncertainity in the dynamic models. The deterministic dynamic models we have spoken of so far, represent not only a simplification of reality. The non-deterministic models represent a better approximation of this reality which leads us to a more realistic way of making decisions. A very new, very flexible and very simple technique tends to stand out of late by using the latest results of a young theory known as the theory of fuzzy sets. The first attempts evinced promising. The dynamic models of a fuzzy type can grasp the real behaviour of the production systems without applying to probability distributions, thus to statistical data, as is the case of stochastic models. This is of particular importance because what the designers of information systems lack are either (precise) common data or (precise) historical data. However, we possess common data, but their precision cannot be guaranteed. To use deterministic models supplied with vague data or stochastic models, when we do not have statistics, means to obtain improper solutions. The fuzzy models seem to answer better reality, with the advantage of a relatively simple mathematics, very much fitted for the computer.

At present, we have new elements which enrich our image about management systems. The spectacular results of the theory of systems compel recognition also in the fascinating domain of the management of economy. Having been validated in other more simple domains — the control of outer space objects is only an example — their penetration into management will undoubtedly bring about an increased confidence in the possibility of controlling the complex economic or social systems and implicitely in the very disputed possibilities of the information systems.

The designing of an informatic management system wants thus to be an exercise of economic cybernetics. A difficult but rational exercise. To design a system avoiding this exercise means to give up the method and then the system no longer seems to have finality. As always, the clarification of background facilitates the application.