



Management Science

Publication details, including instructions for authors and subscription information:
<http://pubsonline.informs.org>

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To cite this article:

(1968) Free For All. Management Science 15(2):B-1-B-10. <https://doi.org/10.1287/mnsc.15.2.B1>

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Guest Editorial

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Man-Machine Systems in the U.S.S.R.

The idea of automated management systems is very popular in the Soviet Union, and one can find the proof of this in recent literature on this subject. Scores of enterprises, departments and even entire Ministries work at establishing such systems on a wide scale.

Since the work carried on in this field will have a crucial impact on various aspects of our enterprises' activity, it is important to consider the causes of such popularity as well as the trends of developments and the conclusions resulting from this.

One may classify the factors influencing the present intensive development of management automation into three categories.

The first category includes economic factors. It deals with the relative difference between the requirements of society and its production capabilities. At present the production apparatus is unequal to the requirements, and the increase in management effectiveness which automation is supposed to provide should help to bridge this gap.

Second, the development of modern techniques as well as the initiative placed in the hands of individual enterprises tend to increase the variety of economic alternatives. The analysis of variants and their selection based on outdated decision-making techniques which are not supported by automated means can prove to be economically embarrassing. The automation of management process may be of essential help.

Third, decentralization which characterizes modern production—when considered from the standpoint of planning and local economic policy development—has proved, not to decrease but on the contrary, to increase the role of centralized control for the total economic complex. But (with a large set of economic decisions being decentralized) only a sharp acceleration in the ability to provide economic analyses will make it possible to maintain the required level of such control.

One may refer technological factors to the second category of causes stimulating the introduction of management automation. The production process is itself important in stimulating technological advances. The ever-increasing specializa-

tion in production acting in conjunction with the growing possibilities for "combinatorial" production resulting in the output of a great variety of articles from a comparatively small number of semiproducts (as has been discussed by M. K. Starr of Columbia University) create a number of new problems. Thus, we must consider the unity of technical and economic information, reducing the difference between them, and storing and processing great volumes of data on the technical parameters of production in the organization memory. There is little possibility that the capacity of organization memory may be increased without the aid of new methodology and automation.

In addition, the peculiar feature of modern production is the increase in the percentage of employees who are working with a relatively fully automated production process. This results in critical shifts in the qualification requirements of the labor force, as well as a corresponding change in the qualification requirements for the activities of management. Management operations in the production field must also become increasingly automated. Disparity between the level of automation in production processes and in management processes will result in an intolerable imbalance of the production system.

Also, as is usually the case with complex problems, the need to solve them appears at a time when ways and means exist for their solution. It was not until electronic computers were designed and found extensive application in technical and scientific jobs, that the problem of management work automation began to assume serious proportions.

An additional stimulus for recent developments is the so-called "machine unemployment" problem, which is related to technological progress. The increase in the number of electronic computers is accompanied by an insufficient rate of use of the machines. The volume of their effective working time comprises only a minor part of total capacity of electronic computers. According to some data it is equal to only 40%–45%. Such a wasteful application of highly effective technical means will not be tolerated by society. The broadest field in which this wastefully spent production capacity might be used is the field of economic analysis.

As mentioned above, the third category of causes stimulating automation development are organization factors. The complex nature of economic decisions gave rise to the division of management work, and to the creation of a complex structure of economic machinery; the considerable inflexibility of this structure has led to the diminution of the management process effectiveness. As a result, there has appeared an urgent necessity to simplify the management man-machine structure. Attempts to simplify this structure by means of traditional rearrangements of sections and departments have failed so far. However, the application of modern information processing techniques promises vast possibilities for simplifying the management of the man-machine structure.

Further, socialist production is being developed as a single mechanism purposefully controlled. That is why we say here that, in principle, the socialist production mechanism is more complicated than the capitalist one. The increase in the complexity of national economy management under socialist conditions must be surpassed by the growing effectiveness of this management. However, the recent period of production development was not observed to be characterized by increasing production effectiveness. This was largely due to the fact that the single control of production was dependent upon data of differing qualities, and because the parallel collection of the same information received different interpretations

at various hierarchy stages. The rational organization of central economic control requires a single and common information base for all the institutions involved. But such a common base cannot function effectively without automation of the management processes.

As indicated above, the appearance of certain problems proved to be connected with the existence of the possibilities of their solution. Automation of management processes is stimulated by the increase in the number and the size of enterprises and organizations working on the mathematical and technical aspects of management functions. This process has become irreversible. The number of institutions applying mathematical methods to economic problems and using electronic computer techniques is steadily increasing.

Lately, however, their effectiveness has diminished. This is due to the lack of a reasonable basis in the manufacturing field for the application of scientific results—and not because the results are intrinsically unsatisfactory. The elimination of this kind of disparity is an additional stimulus to the development of management automation at the enterprise level.

Political factors are also significant. It is worth quoting here a statement made by V. I. Lenin that the development of competition between our two systems will be influenced chiefly by our economic achievements. The development of automated management processes, according to expert evaluation, promises to increase production output without any change in the investment rate; this increase is estimated by Ac. V. M. Glushkov as being 20%, while Ac. L. V. Kantarovitch considers it to be 30%–40%. Even if we halved the least of these two numbers, the expenses should be totally justified.

The task of making a “new man” in the communist society urgently requires that his working time be decreased to allow self-development and also for helping in the process of developing other members of the socialist society. This is particularly important since, at present, the more complex is the modern production process, the more routine and dull is the work carried out by a worker. As a result, greater difficulties are encountered in participating in the social processes. It follows that significant advances depend on the possibility of providing individuals with conditions which stimulate a creative attitude to labor and provide the possibility of applying this creativeness to their activity. Automation in technical fields as well as in management processes is one of the tools promoting such a situation.

In addition, automation is beneficial for the democratization of society. Standardization of repetitive procedures is aimed at releasing some working hours for creative activity. The increased free time of working people released in this way may be used not only for their own development but also to involve them in the management of the enterprise. Thus local resources are uncovered as a means of increasing the social welfare in accord with macro-parameters supplied by society.

Following this outline which characterizes the main thrust of work on management automation, let us consider the development of economic management automation.

The decisions of the September plenary session of the Central Committee of the CPSU on the introduction of a new system of planning and industrial production management—as well as extending these activities to construction and transport organizations of all kinds and also, in the future, to research and development institutions—may be considered as an advance of economic automation processes.

Automation contributes to the self-adaptation of enterprises with a restricted number of sufficiently stable parameters supplied from the center which regulates the country's economy. As a result of the reform being carried on now, such parameters should be prices, production volume and indices of return on capital and/or profit. It is planned to transfer the control of material and technical supply to a self-regulating system based upon the wholesale trade of the production output. That is why we may say that the reform being realized now is a kind of economic automation which enables enterprises to respond to the changes in the environment resulting from internal decisions and from the development of the enterprise itself—irrespective of the instructions given by the center.

Speaking figuratively, before the economic levers of management were introduced, the country's economy resembled the organism of a man who had to think about the necessity to breathe, to blink his eyelids to rest his eyes, and the necessity for his heart to pulsate with a certain rhythm for the blood circulation to be of sufficient rate. But on introducing the new pattern, the most important functions in the *economic* organism are given over to self-regulation.

Only some *limiting* parameters are established purposefully. These parameters of economic activity are elements of centralized planning aimed at solving unique and general problems. The advances in automation have greatly extended the maneuvering space of separate enterprises and, at the same time, increased the number of decisions made by enterprises under conditions involving uncertainty and risk.

We should mention that automation developments have both positive and negative sides. The positive side includes the advantages of controlling additional resources, of increasing managerial incentives, and of accelerating the mastering of new production processes. There is no need to indulge in lengthy discussions on this point. These advantages may be summed up as increasing the flexibility of adaptation to the changes taking place in the economy. We cannot, as yet, have a full view of all the dangers involved in the processes developed. Only when the total set of ideas comprised by the present reform receive complete expression shall we be able to discern the inherently weak points.

However, two main kinds of dangers may be pointed out at present. The increase in the proportion of decisions made under conditions of uncertainty and risk (when initiative is placed in the hands of the enterprises themselves) may result in a greater percentage of decision-making on the part of some plants and organizations, which exceeds the "normal risk rate"—that is, undertaking obligations unwarranted by scientific calculations. This may result in some lack of stability in the work of separate branches, as well as an increase in the number of enterprises which are in the so-called "N2 card index," i.e., enterprises that have changed from producers of national income into its consumers by assuming unjustified risk.

At the opposite extreme is the tendency toward excessive care, and disbelief of the developing freedom of action which is (judging by the press) taking place now. It finds expression in despecialization, in the creation of peripheral, auxiliary production systems (foundry, tool-making, etc.) which might ensure the enterprise against carelessness of suppliers and tardiness of deliveries. This factor may lead to the freezing of capital turnover in the economy, as well as to longer periods for justifying the expenses on investments. The fact that it has been mentioned in the press serves to indicate that it may be widespread.

As antidote to this danger, we may consider two processes which are paralleling the introduction of new forms of industry control. These are the development of a single scientific system of material and technical supply sensitive to the scale of production (the difficulties involved in these developments are great); and the changing role and increasing significance of central guidance in economic problems. This process has been under discussion for several months in the pages of *Pravda* under the title "Time and Style of Work."

In view of all the above-mentioned factors relating to increasing managerial automation, it is necessary to consider now some consequences for management and the enterprise itself. The development of managerial automation requires the making of a new type of manager: one who is able to provide well-grounded decisions in situations of risk and uncertainty, who can control not only economic processes but also social and psychological processes taking place in the enterprise he manages. And here we cannot ignore the appearance of new kinds of relations between the central bodies and the local ones. The growth of independence of the enterprises, as well as the increase in the flexibility of separate organizations, tend to set apart the central bodies from the local ones. Consequently, there may be an increase in the intensity of economic relations between them accompanied by a lessening degree of administrative relations.

The tendency to create central administrative organs that can function on a self-supporting commercial basis (and the encouragement given to this tendency) provides objective proof of the correctness of this prognosis. A new hierarchy of objectives has appeared with the introduction of economic automation. In the structure of branch or territorial management following old principles, the aim of the *central* body (Ministry or Council of National Economy) was the development of production based on *qualitative* parameters (i.e., technical advance, improvement of product quality, etc.). But insignificant material incentives existed for the central body employees in those indices. The objectives of *local* bodies (enterprises) were—under the old conditions—mainly *quantitative* production indices (gross output) where sufficient administrative and material incentive did exist.

Under the reform conditions a redistribution of objectives took place. Significant responsibility for the quantitative parameters was placed into the hands of ministries. It is now their duty to coordinate the output volume of the enterprises they are in charge of. At the same time, a number of qualitative characteristics has been decentralized and placed under the jurisdiction of the enterprises themselves. These include product quality, development of the enterprises' technological bases and the social servicing of workers—which was previously separated from the enterprise management and was principally in the hands of bodies having special powers.

In addition to a new hierarchy of objectives, the automation of economic systems results in the appearance of new measures of responsibility and effectiveness, as well as in a different distribution of responsibility among the central bodies and the enterprises, and also within the separate enterprises.

For the enterprise, decisions taken by the ministry (based upon an altered set of internal economic measures) lead to new results. Automation of the economic system requires quite a change in the approach to the concept of an "enterprise." From the old point of view, the Ministry or Council of National Economy maintained singular control over a great volume of people's property. The enterprise was a comparatively "closed system" lacking adaptive abilities with respect to

the economic medium, and always sensitive to the so-called "center." Under the reform, the enterprise has become an "open system" in the cybernetic sense of the word. It is self-reliant and this fact completely changes the style of enterprise management. The director of the enterprise and his principal deputy directors must now devote their attention to the adaptation of their enterprise to exogenous factors, entrusting to the middle and lower organization levels the endogenous production problems.

All of the above mentioned requirements for the production organization inevitably involve new demands with respect to data circulation and information systems. The development and construction of such transformed information systems in our enterprises has been pursued actively. It represents the second main aspect of managerial automation—that is, the creation of man-machine management systems. This informational automation is developing parallel to that of economic automation—but neither of them can achieve success separately.

At present, the field of information systems is being "attacked" from three sides.

The works on managerial automation being published now contain a great number of papers on the mechanization and automation of primary accounting in the economy, as well as on the problem of creating a single information base for the national economy. This trend is best represented in the works of the Institute of Cybernetics (Academy of Sciences, Ukr. S.S.R.). The system of accounting automation and analysis of economic activity created by this Institute, in collaboration with a number of other organizations at the Lvov T.V. plant, are successful examples of these objectives.

In all of the Institute's publications on management automation, it is the processing of primary economic data by means of modern computing techniques which is called the automated system of enterprise management. And such systems are applicable to the requirements of virtually any economic structure. (Economic reform and the opportunities offered by it are not taken into account here.)

Let us consider three principle cases: 1) Realization of better decision procedures. We may anticipate the gradual introduction of OR models into such systems; 2) Automation of routine, data processing work (arithmetical calculation, data copying, etc.); and 3) Functioning as an advisor—that is, not only processing data, but also suggesting a variety of possible decision strategies which are based on data processing. It is essential that the source of information used by the computer should be primary documents so that all information can be accumulated in the so-called "computer-readable form."

It follows that the system developed in this manner relieves qualified personnel from clerical work, increases the objectivity of knowledge about control processes, shortens the period required to obtain data for management and thus accelerates feed-back, and results in a gradual accumulation of computational algorithms of many different types. As a rule, the automation of accounting operations is achieved first. It is only in succeeding stages that planning problems are solved and multi-variant schemes constructed.

Such systems do not require organizational rearrangement. The structure of the enterprise management remains the same, while a certain number of office workers are released—the computing and accounting operations being passed to ACS (automated control systems). These systems are sure to solve some optimal problems as well.

The works of the Institute of Cybernetics, Ac. of Sc. Ukr. SSR, do not consider social and psychological aspects of the problem at all. This approach which characterizes a large percentage of management automation studies may be regarded as having an "ideological base." Its essential feature is that no major change in the relations among people is involved in the application of electronic computer techniques. Thus, the subordinate role of data processing systems is recognized here as well as in the creation of computer systems which do not qualitatively transform the management process.

The second trend existing in our country is that realized by the Institute of Automation and Remote Control (Moscow) based on the theory of control automation. The "ideological base" of this trend is that the management process is the process of struggle against disorder. The concept exists in physics that any large and complicated system is a totality of elements which undergo accidental effects. In the absence of controlling forces, such a totality of elements tends to disorder. This conception is transferred to the economy. Therefore, we may consider management in economic terms as a struggle against disorder. Automation controls present management with powerful forces that can be used in this struggle.

Since, according to this conception, all management processes may be reduced to informational ones, the conception of controlled systems' entropy is introduced in such a form that the entropy of the system is $E = -\alpha \log B$ where B is the measure of system disorder, i.e., the measure of its disorganization at the inception of managing efforts.

Prior to the above control transformation, the system might be characterized as:

$$E_0 = -\alpha \log B_0.$$

If after the efforts are applied, the system entropy has become $E = -\alpha \log B$, then it follows that the information required to achieve such a change in the ordered system from B_0 to B (supposing that $B < B_0$) will be

$$I = E_0 - E = \alpha \log B_0/B.$$

From these relations we can deduce the principal approach to the problem of control in the economy. One of the important valid assumptions used in this approach is the recognition of strict measures of the information required for decreasing B and the cost of obtaining this information. Further the postulates assumed in this work are based upon a hierarchy of automated, man-machine systems related to one another—as well as the necessity of *uniform automation*. The Director of the Institute of Automatics and Remote Control Ac. V. A. Trapeznikov explains uniform automation as an even decrease in the values B across the totality of automated systems hierarchically ranked with one another.

It should be remarked here that an approach based on the theory of cybernetic control is more complex than one based on mechanization and automation of primary accounting functions. Although it envisages (in latent form) certain changes in the relations among the different hierarchy levels in the national economy, it does not delve into interrelations of the enterprises.

Finally, the third approach follows the line of economic and mathematical methodology and the principles of economic cybernetics (though the concept of economic cybernetics is rather a vague one used in our science). The leading organization in this area is the Central Institute of Mathematics in Economics (CIME)

whose objective is to create a multistage system of mathematical models describing the economic process as a whole. This is intended to embrace all stages, from the department level to the national scale. A single state system of computing centers is used as a technical basis for this system of models.

The results obtained from this system of models must be backed up (according to the principles of CIME) by the corresponding development of economic controls. The existence of such forces helps to stimulate the application of results obtained from the models.

This approach (of CIME) differs from the two mentioned above in that the parallel development of two types of organizations occur *from the outset*, i.e., the technique-information type and the economic type. The qualitative advantage of this approach is that the economic controls are derived directly from the analysis of the model.

The form most widely known for providing control parameters are the "shadow prices" of the linear programming model. The CIME conception differentiates between management processes at different levels. In a practical way, it recognizes qualitative differences between management processes at the branch and national-industry level and those taking place at the enterprise level and inside it.

At the national economic level the basic control requirement of this third conception is the formation of the national economic objectives. They must regulate such processes as capital investment in the total economy, as well as in social and cultural enterprises.

At the branch level, in contrast to that of the national economy, the automated management system (considered from the point of view of technology and information) must service quite a different set of problems: in the main, those which place emphasis on the input-output balance of different branches, as well as problems of location and enterprise specialization.

At the level of the individual enterprises, the automated management system should provide flexibility in the nature of the enterprise's work. Also, it should allow the possibility of timely rearrangement in connection with changes in conditions that affect the branch as a whole (for example, in relation to the relocation of industry planned for the entire branch), as well as in connection with introducing change in the enterprise.

In addition, at the enterprise level, one of the basic functions of the automated management system (in the technological and informational area) is to relieve personnel from overloads in processing information. According to CIME estimates, the present load for one office worker and one member of management personnel is about 8 bits of information per second—and man's ability is only 3 bits per second. As a result some economic defects may take place. In contrast, at the economy level and at the branch level, there is no such problem as decreasing the amount of information processed by the employees of a certain organization (such as Ministry, State Planning Committee, etc.). On the contrary, the problem of maintaining the high quality of information processing required by economic and mathematical models appears. This is a good illustration of the differences involved in solving problems at diverse organizational levels.

It should be noted that particular problems in branch analysis may give satisfactory economic results without simultaneously embracing all of the adjacent and contiguous problems. At the same time, attempts to introduce partial models

for separate enterprises will produce, as a rule, comparatively insignificant results due to the overly simplified character of such an approach. The CIME conception, in contrast to that of the Institute of Cybernetics, Ac. of Sci. Ukr. SSR states that only an approach based on synchronous consideration of all relevant economic problems arising at the enterprise level and based on automated data processing and the total system of models can produce the required results. Nevertheless, at the Institute of Cybernetics there exists the point of view that it is possible to achieve useful economic results although limiting studies to particular problems.

In essence, these arguments can be reduced to a consideration of the organizational topology constructed from the separate enterprises. CIME insists that it is necessary to reconstruct the nucleus of the organization—but this is possible only when all of its elements are modeled together. On the other hand, the conception of the Ukrainian Institute of Cybernetics and that of the Institute of Automatics and Remote Control allow that it is possible to begin with the parts and then gradually pass to the reconstruction of the organization nucleus. (Such ideas are due to Dr. Oskar Morgenstern's works.)

In all the conceptions we have discussed, it is the enterprise alone which responds to the effects of introducing electronic computers. The CIME conception discriminates between national economic or industrial levels and an individual enterprise level. Accordingly, not only organizational and economic factors but also technological factors can be improved by the introduction of electronic techniques. However, no concept can describe the correlation which should exist between economic forces and mathematical models. But, in our opinion, information systems can affect (in a minor way) the social and psychological relations in the organization staff.

Model-building is sure also to have a significant effect both on economic forces and on the organizational relations system. Whenever man-machine systems are used, the structure of an organization undergoes transformation. A number of traditional departments—such as accounting, planning, and finance—are certain to experience serious change. These could include amalgamating them in a single planning and accounting department. The existing conditions in the organization will respond with the substitution of "man-man" type organizations in place of those based on "man-machine" collaboration. Time-sharing systems and the possibility of establishing contacts between electronic computers and a great number of subscribers will result in network re-arrangement that affects the directing centers of the organization. Recent publications on this subject show the possibility of centralization of decisions within separate enterprises due to the introduction of electronic computing techniques. And incentive systems will acquire new accounting bases. This will allow us to abandon the traditional method of economic accounting at the enterprise level, which includes providing individual departments with the same indices that are established for the enterprise as a whole. This will help to make possible a list of target figures and an incentive system for *each* department, corresponding to the character of its work. The sometimes prohibitive complexity of accounting in the incentive system should be eliminated as well.

Here we may point out that the introduction of computing techniques and the relieving of employees of a great deal of routine work will result in a redistribution of labor according to specialization. Enterprises which now specialize according

to two principles, i.e., labor product and labor process, will inevitably pass to three principles of labor specialization with the introduction of electronics and mathematics, viz., according to labor product, labor process, and the problems to be solved. These trends require serious analysis.

It is estimated that up to 40% of the managing operations within a separate enterprise can be automated. We think it possible that the above figure may be increased up to 60%–70%. However, to achieve such a level, a number of conditions must be met.

First is the shift to the field of management by individuals of exceptional skills and talents. Second is the elimination of random change in the data supplied. Third is the need for a single terminology which can be used generally in the management process. (At present, a special commission is working on the establishment of such a terminology.) Fourth is the accuracy of the symbols used in the terminology. Fifth includes new planning techniques to enable individuals, working under the altered conditions of "man-machine" systems, to make a careful prognosis of the future. This is most important if we hope to bring the decisions that are made into practical usage.

In conclusion, we may agree with the estimate that the development of man-machine systems during the next 10–20 years will make it possible to automate the majority of the processes connected with decision-making which are presently used by individuals to achieve economic results. However, we should note that this development will be affected by the specific social and economic conditions existing in the U.S.S.R.

We can expect an increase in the total effort to analyze management and organization problems on a national scale. Similarly, the study of separate enterprises will increase due to the growing democratization of managerial processes.

The single control of national economic processes and the absence of a spontaneous market should help to develop centralized regulation of major economic problems and decentralization of decisions. Such a development will reflect the sharp differences between management functions and economic problems at national and local levels.

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