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The Consequences of Computers for Centralization and Decentralization **Herbert A. Simon**

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Today, the terms *centralization* and *decentralization* are heavily laden with value. In general, decentralization is the good thing and centralization the bad thing. Decentralization is commonly equated with autonomy, self-determination, or even self-actualization. Centralization is equated with bureaucracy (in the pejorative sense of that term) or with authoritarianism and is often named as a prime force in the dehumanization of organizations and the alienation of their members. If the reader shares these common attitudes toward centralization and decentralization, I shall ask him to hold them in suspension until I have inquired more closely into their meanings.

THE NATURE OF CENTRALIZATION AND DECENTRALIZATION

Picture a typical organization in hierarchical form with various decision-making functions being carried out at the nodes. Centralization is any transfer of such functions from a lower node to a higher one, decentralization any transfer from a higher node to a lower one. Centralization is always a relative matter, for decision making is never fully concentrated at the very top or at the very bottom of an organization. When we ask what effect computers will have on the centralization and decentralization of the institutions and organizations of our society, we are asking in what direction they will move the balance. It is perfectly possible, of course, for both movements to go on concurrently in an organization, some functions being passed upward at the same time that others are passed downward. Thus, in the 1950s, many production and marketing decisions in large

Herbert A. Simon is University Professor of Computer Science and Psychology at Carnegie-Mellon University. He is noted for his writing in many areas—political science, management, computer science, and psychology—and received the 1978 Nobel Prize in economics for his work on management decision making. He is also a winner of the Association for Computing Machinery's Turing Award for his pioneering work in artificial intelligence.

American corporations were being decentralized to product divisions at the same time that labor relations decisions were being centralized.

Functions of Centralization

There are three main motives for centralizing decision functions: to gain economies of scale, to coordinate interdependent activities, and to control lower-level activities in the interest of higher-level goals.

1. In decision making, economy of scale means mainly creating central units for handling certain classes of decisions expertly, where it would be too costly to distribute experts more widely through the organization—a classic application of Adam Smith's principle of the division of labor, although in this case the labor is mental, not physical.

2. The interdependencies that make coordination desirable are those that the economist calls externalities; that is, actions whose consequences fall on a part of the organization other than the one taking the decision. These external consequences may be undervalued or ignored if decisions are not centralized. It may be possible, however, so to design the reward system that a decentralized decision-making unit will be charged fully with the indirect consequences of its actions, in which case interdependence ceases to be a reason for centralization. Pricing mechanisms provide an important means for reconciling decentralization with interdependence whenever appropriate prices can be assigned to all of the relevant consequences of an action. On the other hand, prices that do not reflect important externalities can be a cause for divergence between decentralized decisions and higher-level goals, and hence a motive for centralization.

3. Even without interdependencies among units, some measure of centralization may be thought necessary in order to guarantee that the actions of individual organization units will reflect the goals of the whole organization. Successful decentralization assumes that lower-level administrators can be motivated to make their decisions in terms of higher-level goals.

Decision Premises

Making a decision involves weaving together many diverse premises—goal premises, constraints, side conditions, and factual assumptions based on data and theory—and deriving from them the choice of a course of action. Centralization need not involve transporting the whole decision process from one node in an organization to a higher one but may consist in establishing and communicating from the higher node one or more decision premises, with the injunction that they be employed in making the decision. One organization unit may provide another with objectives, with rules and constraints, or with facts. A single decision, then, may be

manufactured out of a diversity of component materials that were themselves fabricated elsewhere in the organization.

It is important to view decision making as more than just the final signing on the dotted line. The decision-making process in an organization encompasses (1) determining what items will be on the agenda and receive attention; (2) inventing and designing alternative plans of action; (3) evaluating alternatives and making the choice; and (4) postauditing decisions and their consequences. If we take a longer view, we also have to include in the decision process all the varieties of investigation and research that build the organization's understanding of its environment and of the laws by which it operates. It is from this understanding that the invention of plans of action proceeds, as well as the estimation of decision consequences.

Decision making begins, then, with activities directed toward understanding the environment, proceeds through attending to selected aspects of the environment and the problems it presents, to devising courses of action, choosing among them, and reevaluating them by hindsight. For example, the energy shortage and rising energy prices may cause a company management to attend to the reliability of its energy supply and the efficiency of its use of energy. Means may be sought, discovered, and adopted for insulating buildings, reducing the energy requirements of manufacturing processes, or remodeling power plants to enable them to use alternative fuels. This whole stream of activities constitutes the decision-making process.

Decision premises do not only flow downward through the organization's channels of formal authority; they also flow upward and sideward. If the higher organizational levels provide authoritative instruction and information for decision making at the lower levels, the lower levels also provide much of the information that goes into higher-level decisions. In the unhappy history of the Vietnam War, no small part was played by the "body counts" and other local assessments of the battle situation that flowed upward to the top command in Saigon and thence to Washington. Whether this information was believed, or only partly believed, it provided a substantial part of the "facts" on which the decisions of war or peace were based. The information received by the top organizational levels is not always as bad, fortunately, as it was in this instance. In any event, it is typical of organizations that a large proportion of the facts for decision making at all levels originate either near the bottom or in specialized units outside the chain of command that perform one or another kind of expert or intelligence function (e.g., economic forecasters, market analysts, research and development departments).

Where decisions involve resource allocation, as they commonly do, much of the needed information can be encapsulated in the form of prices

of inputs and outputs to each particular organization unit. Clearly the dissemination of this kind of information is not limited to any particular communication channels. Hence, where prices can be used to represent interactions, the decision-making process can be carried out in close proximity to the points where the decisions will be executed. Whether an increased communication flow to a decision center means more or less centralization of decision making depends, therefore, on whether the flow is from a lower level in order to inform decisions at a higher level, from a higher level to control decisions at a lower level, or from some expert source to a collateral point of decision making. Reduced autonomy for a high-level decision maker may imply a greater degree of decentralization (i.e., increased reliance on decentralized information sources) rather than centralization.

Perception of Autonomy

The premises of any particular decision may have their origins far back in time and may be stored in a variety of repositories—human memories, organization records, or books—before they are brought to bear on that decision. How centralized or decentralized we regard the decision as being will depend on whether we trace back these premises or consider only where they were stored at the time the decision was made. Herbert Kaufman, in his classic work, *The Forest Ranger*, describes a highly decentralized decision-making system in which the district ranger in the Forest Service exhibits great autonomy within his district. But Kaufman also shows how the forest ranger's training and indoctrination have instilled in his memory the decision premises—both goals and techniques—that give the organization confidence that he will work toward its objectives and will do so expertly and predictably. Thus, in this case and many others, autonomy in decision making goes hand in hand with the internalization of goals and the knowledge that make decentralization safe from the viewpoint of the higher levels of the organization.

From the standpoint of the autonomous decision maker's attitudes and motivation, it makes a great difference whether the premises on which he is acting have been received in the form of directives from other parts of the organization or whether they have come from his own memory, where they have long resided and become part of himself. But suppose one of his decisional premises comes neither from a directive nor from his memory, but from a reference book? Does he then view himself as acting autonomously, or under direction? Suppose it resides in a computer memory that he interrogates from a terminal? Is he acting autonomously, or is he being controlled by the computer?

His perception of his autonomy in these circumstances may depend on

what motivated him to consult the book or computer memory in the first place. Was he instructed to do so by an organizational directive? Did his professional training teach him to turn to this source? What confidence does he have in the validity of the information? Clearly, autonomy resides in the mind of the decider and in his identification or nonidentification with the various parts of his informational environment. Any conclusions we draw about the implications of computers for centralization, and particularly its psychological consequences, must be carefully weighed in terms of the decision maker's attitudes toward the sources of information on which he draws and the extent to which he has internalized his recourse to those sources.

Feasibility of Centralization

Finally, the degree to which decisions are centralized or decentralized in an organization depends not only on the desirability of one or the other mode of operation but also on its feasibility. Any change in technology that makes it cheaper and easier either to centralize or to decentralize decisions will tip the balance in that direction.

COMPUTERS AND COMMUNICATION

An analysis of the consequences of computers for centralization and decentralization must take account of the electronic communications systems in which computers are embedded. It may even be that the communications systems, with or without computers, are of more import than the computers themselves.

Effects of Modern Communications Technology

Modern communications technology was introduced long before the computer. First the telegraph and cable, then the wireless, and then the telephone revolutionized communication at long distance. Already in the nineteenth century, the autonomy of ambassadors was greatly curtailed by the possibility of communicating almost instantaneously with the foreign ministry in the home capital. The same is true of overseas executives of corporations. On the other hand—and there almost always is another hand—the speeding up and cheapening of international communication and transportation greatly increased the volume of international transactions.

As a consequence of these countervailing trends, it is not obvious that the foreign representative of a governmental or business organization perceives himself as having less decision-making responsibility than his ancestors had. On the one hand, it is easier to instruct him. On the other

hand, there is much more to instruct him about. Moreover, these communication links are two-way links; they enable the foreign representative to inform and advise the home office as readily as they enable the home office to inform and instruct him. As the costs of long-distance communication go down and the volume of information that can be transmitted increases, the opportunities for low-level inputs to high-level decisions are greatly enhanced. As I have already shown, this is a force toward greater decentralization.

These comments apply, of course, not only to international communications but also to communications within a single country, a single city, or even a single office building. Large volumes of information can flow electronically between any two points in an organization where it pays to install a broadband communication link, and the cost of such a link decreases each year.

The fact that information can be transmitted to a decision point does not mean that it can and will be used there. The world of modern communications is an information-rich world, in which the problem of absorbing information is generally perceived as more acute than the problem of generating or transmitting it. A decade ago, the U.S. State Department "modernized" its communications system by installing fast line printers to handle the traffic of messages from foreign embassies. Nothing was said about how the department staff would deal with the inundation of messages. Today, improvements in the efficiency of such a system would certainly encompass information filtering and information compression, as well as transmission.

Characteristics of the Computer

What can be done faster and better with a computer than without it? A computer can analyze the behavior of systems with many interacting variables—systems much too large to analyze without its help. It can store sizable bodies of information, indexed so as to meet a great variety of information needs. It can copy, input, and output information with great speed. And it can do all of these things not only with numerical data but with information in various forms, including natural-language texts and other nonnumerical information. Moreover, next year its descendants will be able to handle more information faster and cheaper than it can.

Modeling and Analyzing Interdependent Systems

The ability of the computer to model systems with many interdependent variables was exploited in one of its early management applications: making ordering, inventory, production, and shipping decisions for large, geographically dispersed manufacturing operations. These were deci-

sions that had previously been made by factory and warehouse inventory managers and schedulers; hence the introduction of the computer has brought about a substantial centralization of these activities in many companies, where it has produced large reductions in average inventory holdings. It is undoubtedly the most striking example of computer-produced centralization, but it is perhaps not typical of the ways in which computers have been used.

A different use of computers to analyze complex systems of interdependent variables are the models of energy systems or combined energy and environmental systems that have been constructed in the past several years to help guide the formation of public policy. Here is another case where the power of the computer is needed to assemble a previously fragmented structure of numerous interacting mechanisms. But in instances like this it would be misleading to say that the computer brings about centralization. It would be more accurate to say that it allows a systematic, analytic approach to problems that previously were addressed in an unsystematic, almost chaotic way. It is not that energy policy was previously arrived at in a decentralized way; it is that there was no energy policy. The cause of centralization, if there has been any, is not the computer but the need to address the whole problem rather than isolated fragments of it. The computer enhances our ability to do this; it does not create the necessity for it.

Similarly, building a model of the economic and market environment of a corporation does not centralize management decision making so much as it allows top management to adopt an orderly, analytic approach to decisions it had already been making—but by seat-of-the-pants methods. Taking account of relevant variables that had previously been ignored is not to be confused with centralizing the locus of the decision process.

Two related fields of research, operations research and artificial intelligence, have built tools to enlarge the capabilities of computers for modeling complex systems and have devised more and more powerful analytic techniques for this purpose during the past thirty years. Of course these tools are applicable to a particular set of phenomena only to the extent that the phenomena themselves are understood. But the combination of research on systems analysis techniques with basic scientific research is permitting us each year to approach complex decision problems in business organizations and in the public domain with greater sophistication.

Information Storage and Retrieval

One form of centralization, although not necessarily of decision making, is the gathering of large bodies of information into central computer memories as the basis for information retrieval systems of one kind or another. An airlines reservations system is an interesting application of

this sort, particularly because it involves remote access to the central memory over long distances. It can be seen that in this instance hardware centralization does not bring about any centralization of decision making. On the contrary, it allows each of the decentralized decision points to take actions independently, confident that automatic updating by the central memory will take care of all interactions among decisions.

An example of a different sort is the computerized systems for medical diagnosis that are just on the verge of moving from research and development into practical application. Let us suppose that a perfected version of such a system existed in some central location where it could be accessed from remote terminals. By an interactive procedure, information about the patient would be entered, say, from the local hospital. The system could request additional information or ask that additional tests be performed on the patient before arriving at a diagnosis. By any reasonable definition, such a system would represent a centralization of the decision-making process, even if its diagnoses were only advisory. But the important question is the psychological one: would the physician perceive the system as replacing him in his diagnostic function, or would he perceive it as a tool—like penicillin or an X-ray machine—to help him carry out his task? The answer to this question probably depends on the way the system is introduced and the institutional framework within which it is used. Physicians, after all, do not usually regard reference books as threatening automation of their functions, however good the answers or advice they may obtain by consulting them. The automated diagnostic system can simply be regarded as a more powerful and more easily consulted reference book—or it can be regarded as a "robot doctor." What it "really" is lies mainly in the mind of the physician.

TRENDS IN COMPUTER TECHNOLOGY

During the first twenty or so years that computers were on the scene, they had two characteristics that suggested their widespread use would inevitably move decision making toward centralization. The first was that the efficiency of computers increased rapidly with their size: a single large computer was substantially cheaper (perhaps by a factor of three) than ten small computers of the same aggregate computing power. The economics of scale seemed to argue for one or a few centrally located computers rather than many computers distributed through an organization. The second characteristic of early computer systems was that they could only be used by someone in physical proximity to them. Therefore, if the computers were geographically centralized, so would be their use.

In the past decade advances in technology have made drastic changes in these two characteristics, and the shift is still continuing. Minicomput-

ers have been developed that for many purposes compete very well in efficiency with the largest computers. Economies of scale no longer provide a conclusive argument for centralization. Second, and perhaps even more important, with time sharing and remote access, many users in different locations can share the same central computer. (As the examples of the plane reservation system and the medical diagnosis system show, not only can processing capacity be shared, but also access to a memory bank.)

With the new and emerging computer technology of minicomputers, time sharing, and remote access, the decisions about where to locate components of the decision-making process can be pretty completely detached from decisions about the hardware configuration. Of course, long-line access to computers is not without cost, but the costs are relatively low today and still dropping, so that it is not at all unreasonable to look toward the development of nationwide networks. In fact, several experimental networks of this kind (in addition to special-purpose networks like the reservations systems) already exist.

THE IMPACT OF COMPUTERS ON ORGANIZATIONS

Although the computer revolution is far from having run its course, it has been under way for thirty years, and by now we have accumulated a considerable body of experience that should help us predict its direction. Its most visible consequence to date has been the automation of many clerical information-processing functions in accounting departments, insurance companies, and banks. This development, however important it may be from other standpoints, has no particular implications for centralization or decentralization.

Operations Research

Another consequence of the computer revolution is the centralization of middle-management decisions relating to inventory, production scheduling, and the like. At the same time, there has been a great expansion in the use of formal operations research models for making many kinds of middle-management decisions. At the outset, the introduction of such models probably caused some centralization of decision making in special operations research departments, but this was a transitory phase of a kind that often occurs when a new technology requiring specialized knowledge is introduced into an organization. As soon as knowledge of operations research techniques was diffused widely enough to become a part of the standard equipment of industrial engineers and other managers at middle levels, the decision-making responsibilities tended to return to their previous locations in the factory and departmental organizations. Middle man-

agers now make some different kinds of decisions than they did traditionally, and use management-science tools in making many of them, but the management-science tools have become *their* tools and are not generally viewed as removing them from the decision process.

Strategic Planning

The spread in the use of complex models as an aid to decision making has not been limited to middle-management decisions. I have already mentioned the governmental use of models to aid in making decisions about energy and environmental policy. Increasingly, corporate planning at top management levels is being informed and assisted by a variety of computerized analytic techniques (systems analysis), including modeling of the firm itself and its economic environment.

The growing use of modeling as a component of strategy formulation and strategic planning has led to some expansion of corporate planning staffs and their counterparts in government agencies to carry out this function, producing new flows of information and advice from these staffs to top management. Again, it is difficult to interpret this development as an increase in centralization. What it principally means is that a considerable amount of managerial and technical effort all up and down the line, which previously was devoted to day-to-day decision making, is now devoted to the design of the decision process itself and to developing and maintaining the basic models and data bases required for strategic analysis. The change in managerial role is analogous to the change in supervisory role with the introduction of automated control into processing plants, where the main task of foremen and supervisors shifts from making operating decisions to maintaining and monitoring the performance of the automated decision system.

I should insert parenthetically, because there has been some confusion on this point, that the development of strategic planning systems and techniques has had relatively little to do with the development of so-called "management information systems" (MIS). Most of the MIS work has been aimed at computerizing existing internal accounting and production records systems and incorporating in them procedures (usually elaborate) for producing reports addressed to management at various levels. Experience with management information systems has generally been disappointing, mainly because insufficient thought was given to the nature of the management decisions they were to inform and because it was not realized that the important function of computers in organizations is not to multiply information but to analyze it so that it can be filtered, compressed, and diffused selectively. The systems that have been designed under the strategic planning label are generally more relevant for these purposes than are typical MIS systems.

The Qualitative Change in Decision Making

In summary, the very large impact that computers are having on business and governmental organizations cannot be described in terms of centralization and decentralization. What is occurring is a profound qualitative change in the decision-making process, which is being formalized, made explicit, and subjected to deliberate planning.

As decision processes become more explicit, and as their components are more and more embedded in computer programs, decisions and their underlying analyses become more and more transportable. If the method of analysis is explicit and the informational and other premises that enter into it can be specified, then it does not matter very much at what organizational locations the analysis is carried out. As a matter of fact, it becomes increasingly feasible to carry out alternative analyses, using different assumptions and even different decision frameworks and analytic techniques, and employ them all as inputs to the final decision process. With all sorts of organizational and extraorganizational sources providing inputs, the locus of decision making becomes even more diffuse than it has been in the past. The organizational hierarchy remains as a critical mechanism for monitoring the process, but an increasing part of the flow of decisional premises overlaps the boundaries of the formal hierarchy.

IMPLICATIONS FOR THE POLITICAL SYSTEM

Decentralization has entered the political rhetoric of our time in the discussion of two related questions about the organization of our governmental system. The first of these is the question of the relations among the different levels of government, national, state, and local. The second is the question of the participation of citizens in the governmental process. Although often discussed together, these really are separate issues which should be looked at individually.

Federal, State, and Local Relations

There is a long-standing myth abroad in America that local government is "closer to the grass roots" than state government and state government closer than the federal government. In the purely numerical sense that each person represents a larger fraction of the electorate of his city than of his state, and of his state than of the nation, the claim is undeniably true. But it does not follow from this arithmetic that each person has a greater influence on local decisions than on state decisions, or on state decisions than on national ones. It could be argued, in fact, that because it is easier to focus public attention on major national issues than on state or local ones, there is greater popular influence on national decisions than on the

others—the Vietnam War and the impeachment of Nixon being cases in point. The principal mass media in this country, and particularly TV and the news magazines, attend largely to national affairs, attracting public attention to them to the relative neglect of what is going on at the state and local levels. While political participation is highly selective at all levels of government, it is probably most selective at the state and local levels.

As a matter of fact, the transfer of power from national to local government, a policy that has had wide popularity during the past few years and especially during the Nixon administration, is not motivated primarily by the desire for greater public participation in government decisions. Part of the support for the movement does come from advocates of participatory democracy, but a much larger part has had two other motives: (1) equalization of the disparate financial capacities of the states and cities to provide governmental services; and (2) the desire of a conservative administration faced by a liberal Congress to put power back in the hands of state and local governments believed to be more congenial than Congress to the administration's point of view.

That government in the United States has tended to become more centralized over the years cannot be doubted. It has become more centralized as activities throughout the nation, and particularly economic activities, have become more interdependent. A highly integrated economy with a highly mobile population cannot behave as though it were fifty independent states or three thousand independent counties. Any important trend toward decentralized decision making is unlikely to occur unless technical means can be found to deal with the real interdependencies that exist.

All of this is preliminary to putting two questions about computer technology: (1) Has the computer contributed, or is it contributing, to the movement toward centralization in American government? (2) Does the computer provide means for checking or reversing that movement? From what has just been said, it is reasonably clear that the answer to the first question must be no. The trend toward centralization long predated the computer, and is adequately explained by other causes. Nothing I have said about computer technology suggests a positive answer to the second question, either. However, there have been some claims, and even some experiments to verify them, alleging that the computer could become an important means for enabling citizens to participate more fully in public decisions. I should like to examine those claims next.

Participatory Democracy

A few years ago, a well-known physicist proposed putting a simple electronic voting device in all homes, so that a referendum could be held

almost instantaneously on any issue. The same suggestion has been made by others, and an experiment along these lines appears to be under way at the present time in a West Coast community. Such a device would certainly go a long way toward solving one problem—that of ascertaining the state of opinion of any citizen on any issue at any time. (I hope provision would be made for a “no opinion” response!) The question is whether this is the problem that needs to be solved in order to enhance anything that could justifiably be called citizen participation.

The genius of democratic government is not arithmetic; it is informed consensus. Most questions of public policy do not begin life as dichotomies that can be decided by yes or no. Yet courses of action must be framed and decisions about them reached. Democratic institutions define a process for getting issues on the agenda, generating proposed courses of action, and modifying and amending those proposals until some measure achieves enough support to be enacted, but only in the most specious sense can we say that the chosen course represents the will of the majority. There is almost never a single action that is preferred by a majority over all alternative actions. There may, of course, be a majority preference for that action among all politically feasible actions—where “politically feasible” is defined by the decision process itself.

Different democratic systems define differently the processes for forming majorities. In many European democracies, the legislative body consists of members of numerous political parties, each having a more or less definable ideology and none commanding a majority. In such systems, the formation of coalitions among parties, a process in which each of them relinquishes some of its ideological purity, plays a central role in the formation of majorities. In the American system, with two amorphous political parties with almost unidentifiable ideologies, one of which is usually able to form a legislative majority, the formation of majorities is accomplished primarily through the process that creates and maintains the parties themselves.

This is not the place to enter into a lengthy discourse on political institutions, beyond demonstrating that they are not merely or mostly mechanisms for counting noses. To be sure, elections play a major role in our system and referenda a significant role in some states. But the question to be asked about elections and referenda is not whether the alternative finally chosen obtained a majority or plurality vote, but whether the process by which the decision was reached commanded consensus, whether the decision bore some reasonable relation to informed preferences, and whether—a point I wish to elaborate—the process was spacious enough to accommodate fact and reason along with all the other factors that enter into the formation of public opinion.

The political process, then, is not simply a mechanism for recording a majority of opinions already formed. It is a process for reaching decisions, often about complex matters of policy, in the light not only of already existing goals but also of the probable consequences of alternative courses of action. When we have legislative and public debate about measures to be taken to protect the environment, it is not that there are some people who are "for" the environment and others who are "against" it. There are deep disagreements, some about values, but most about the magnitude and seriousness of the consequences that would follow protection or failure to protect. Is the benefit to public health that will be gained by reducing the NOx emission standard for automobiles to 0.4 grams per mile substantial enough to justify the expenditure of several billions of dollars to achieve it? On many, if not most, questions of this kind, disagreement stems much less from conflicts of interest than from uncertainties about outcomes. Even where both are involved, we probably would regard it as an improvement in the democratic process if its participants could make more accurate estimates of where their interests lay.

Informing Public Opinion

If the computer has any implications for the effectiveness of democratic institutions, they have to do with the processes for forming and informing opinion rather than the processes for recording it. The computer enters as a tool that permits policy alternatives to be examined with a sophistication and explicitness that would otherwise be impossible.

Already one can begin to point to examples where the computer, used in conjunction with the tools of systems analysis, is beginning to play such a role. The debate on federal financing for the SST is one such example, the debate on the antiballistic missile is another. In both these cases, intelligent public debate was facilitated by analyses, some of them aided by computer, of what might result from choosing one alternative over another. With such analyses available, their assumptions explicit and open to examination and question, a layman could acquire not merely an opinion on the policy issue but an informed opinion.

Over the next decade, I think it is predictable that the computer is going to play an even more important role in helping us to understand the choices with which we are faced in matters relating to energy and the environment. The complexities here are an order of magnitude greater than in the SST or ABM decisions, and there is probably greater consensus about the values to be served by the decisions. But the computer is simply a tool in the process that enables us to calculate interactions better than we could without it. It will help us only to the extent that we have valid scientific theories of the systems whose behavior we are trying to model

and predict. (It will help us too, of course, in developing and testing those theories.)

The effectiveness of democratic institutions, as well as people's confidence in them, depends in part on the soundness of the decision-making processes they use. Democracy does not require a town meeting in which every member of the public can participate directly in every decision. But it is enhanced by an open and explicit decision process that enables members of the public to judge on what premises the decisions rest and whether the decisions are informed by the best available facts and theories. In fact, such a decision process is a precondition to intelligent public participation of any kind. To the extent that computers can contribute to its growth, they can strengthen democratic institutions and help combat public feelings of helplessness and alienation.

CONCLUSION

I began by arguing that there are three main motives for centralizing the decision-making process: to gain economies of scale (expertness), to coordinate interdependent activities, and to control lower-level activities in the interest of higher-level goals. I went on to examine the implications of computer technology for centralization and decentralization in both management decision making and the formation of public policy. What remains is to show how the introduction of the computer affects the motives favoring centralization, hence tipping the balance in one direction or another.

The computer is making major contributions to raising the level of expertness in decision making on complex matters. It is doing this, however, not by concentrating the decision process at higher levels of management but by either (1) facilitating the construction and use of systems models that can incorporate expert knowledge about system structure and system behavior or (2) permitting the assembly of expert knowledge in large data banks that can be consulted readily from any organizational location provided with a terminal. It is a psychological question whether these sophisticated aids to decision making will be perceived as reducing the autonomy of executives or as enlarging and extending their capabilities. If care is taken in the ways in which computerized decision aids are introduced into organizations and employed in them, there is no reason why they should either be or appear to be centralizing mechanisms.

There probably exists a continuing long-term trend toward the centralization of decision making in both business and government as the matters about which decisions have to be made become more and more interdependent. It has perhaps been slowed but certainly not halted by the use of price and market mechanisms to reconcile interdependence with

decentralization. It does not appear that computers have contributed to this trend. What they have contributed, through the modeling capabilities already mentioned, are powerful new means for decision makers to deal with problems involving large numbers of interacting variables. Decisions will not be more centralized as a result of the introduction of computers, but centralized decisions will be made in a far more sophisticated way, taking a fuller account of the real-world complications of the situation, than was possible before.

The use of computers in decision making has important implications for control over the goals to which administrative action and policy are directed, but these implications can as easily support broader as narrower participation in goal setting. What computers do in this respect is mainly to open the decision process to inspection. They objectify the process and make fully explicit the premises of fact and value that enter into it. As a result, the use of the computer will facilitate top management's control over decisions made elsewhere in the organization—in this way reconciling the notion of central control over goals with the notion of decentralization of the actual decision process.

More generally, the use of computers will permit multiple inputs into the decision process from a variety of sources, along with mutually independent alternate analyses of problems. In this way, computers will facilitate—and already have facilitated—a more extensive participation of both experts and laymen in debates on public policy, not by providing means for expressing uninformed opinions but in enabling opinions to be better informed.

Modern communications and computers have moved us from a world in which information was a scarce, valuable commodity, to be cherished and preserved, to a world so full of information that what is scarce is the capacity to attend to it. The computer has often been used incorrectly, as in many MIS systems, as a producer of information. Increasingly, we are learning to use it as a compactor of information, reducing the amount of data managers and policymakers must absorb and shouldering an important part of the burden of analysis that transforms a multitude of premises and predicted consequences into a decision to embark on a course of action.

Whether we employ computers to centralize decision making or to decentralize it is not determined by any inherent characteristics of the new technology. It is a choice for us to make whenever we design or modify our organizations. The technology does offer us a wide range of alternatives for fitting our decision-making systems to our requirements, whatever they may be.

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