chapter sixteen

Organizations and Technological Change

Organizations are a dominant part of modern life. Most of us are born in organizations, are educated in them, spend our working lives in them, and when we finally depart from this world one organization takes care of our mortal remains while another attempts to ease our passage into the hereafter. The pervasive influence of organizations has stimulated a considerable amount of research on their relationship to technological change. We will first consider how organizational structures are affected by technology. After that, we will turn things around and look at how organizational structures and processes can influence the course of technological change.

Technology as a Cause of Organizational Structure

Much of the research on the interaction between organizations and technology has been concerned with how technology has affected organizational structures and processes. Many of these studies have come to the conclusion that an organization's structure—the extent to which authority is centralized, the amount of worker specialization, and the number and importance of formal rules—is strongly influenced by the principal technology that the organization uses.

One such study was conducted by Robert Blauner.[1] Blauner focused on a number of different industries that exemplified particular types of technologies and how they affected work. Printing, for example, was characterized by a set of activities reminiscent of traditional craft occupations that required a high degree of worker skill and involvement. Conducting his research at a time before the invention of computerized typesetting equipment, Blauner found that the absence of specialized machinery resulted in a work environment that allowed a great deal of worker autonomy. In contrast, textile mill operatives were little more than machine-minders. Their activities had to be closely attuned to the demands of the equipment, so there was little room for individual initiative. Assembly line operations took mechanization to an even higher degree, and forced the worker to submit to a rigid scheduling of activities that was dictated by the inexorable movement of the line. Finally, continuous process industries, such as chemical manufacture or oil refining, made use of highly sophisticated technologies, but unlike textile production or automobile manufacture, they required considerable

worker involvement and initiative. Workers had to carefully monitor production processes and take decisive action when the inevitable problems occurred. Their work could not be precisely scheduled or regulated, and they enjoyed a considerable amount of on-the-job freedom.

Where Blauner's study focused on the relationship between the technology used by an industry and its effects on workers, Joan Woodward's inquiries centered on how different technologies affected organizational structures per se.[2] Of particular concern to her were such variables as the number of levels in the managerial hierarchy, the ratio of managers to other personnel, the number of people supervised by first-line managers, and the flexibility of the managerial system.[3] Woodward was not concerned with individual technologies, but with general manufacturing processes. Her mode of analysis made use of three broad categories: unit and small-batch production (such as shipbuilding or the manufacture of large transformers), large-batch and mass production (as exemplified by automobile manufacture), and process production (such as the production of chemical or petroleum products).

According to Woodward, each of these categories is distinguished by differences in technological complexity and the extent to which uncertainty can be reduced through the application of routine procedures. These differences in turn resulted in different types of organizational structures, each with their distinctive processes. Mass-production technologies required routinized processes, narrowly defined job duties, and a clear hierarchy of authority that kept a firm grip on things. In contrast, the two other methods of production—unit production and continuous process production—were much less rigid in their operations, and had a regular flow of worker–management communication that was not filtered according to hierarchical position. In similar fashion, the span of control—the number of workers under a single supervisor—was greatest in firms using mass-production technologies. Other kinds of organizational differences also seemed to reflect production technologies. Managerial specialization occurred more frequently in mass-production firms, and process production technologies required a higher ratio of managers to other personnel than was the case in organizations using different productive technologies. More relationships could be cited, but Woodward's essential point is that organizational forms must be matched to production technologies. In practical terms, a successful organization is one that uses structures and procedures that are appropriate to the productive technology employed.

A final example of an organizational theory guided by a consideration of technology is provided by the work of Charles Perrow. Perrow's theory is pitched at a more general level than those of Blauner and Woodward. Instead of considering particular types of production technologies, Perrow considers two basic aspects of the work undertaken within an organization: the degree of variability of the raw materials processed by the organization, and the extent to which problem-solving procedures can be routinized. By raw materials, Perrow does not mean just inanimate objects; iron ore is a basic raw material for a steel mill, but for an employment agency people are its major raw material. In "processing" its raw materials, an

organization will confront different degrees of difficulty. Perrow's analysis of the problem-solving process centers on the number of exceptional cases that must be confronted and the extent to which the search procedures can be reduced to a routine. Different kinds of organizations are characterized by different combinations of these elements:[4]

Few exceptions and analyzable searches	routinized organizations—e.g., steel mills; custodial institutions—e.g., prisons
Few exceptions and unanalyzable searches	craft industries—e.g., custom-made products; socializing institutions—e.g., schools
Many exceptions and analyzable searches	engineering firms—e.g., heavy machinery; programmed learning schools
Many exceptions and unanalyzable searches	nonroutine manufacturing—e.g., aerospace; therapeutic institutions—e.g., elite psychiatric hospitals

Perrow's implicit definition of technology is quite general and abstract; technology is defined as a way of doing things, and Perrow is not concerned with the material artifacts that are part of the technology employed. What is important here is the nature of the raw material and methods needed to convert it into the organization's products. Above all, Perrow is concerned with organizational effectiveness. A major conclusion of his analysis is that the organizational structure should reflect the particular qualities of the raw materials being used and the technology used for their transformation. To be effective, an organization must use technologies appropriate to its tasks. His conclusions are thus similar to Woodward's: there is no such thing as an optimal organizational form that is universally valid. Everything depends on how things are produced and the materials from which they are made.

These studies, and others like them, have sensitized organizational theorists to the influence of technology on organizational structures and processes, albeit at the risk of drifting toward technological determinism. Yet at the same time, few hard-and-fast conclusions can be asserted. Some empirical studies have found no relationship between an organization's technology and its structure,[5] but taken as a whole, research into organizations has shown that their structures are influenced by the technologies that they use, although the relationship is not particularly strong.[6]

The lack of a close relationship between technology and organizational structure is understandable, given the complexity of most organizations. Rather than making use of a single technology, organizations employ a variety of technologies, especially when they have numerous functional divisions. An R&D laboratory and an accounting office may be components of the same organization, but their technologies will differ substantially. Accordingly, the linkage between technology and organizational structure is likely to be more evident when the basic element of analysis is the work unit rather than the organization as a whole. Even here, the relationship is not likely to be an exact one, as the size of the organization

and its components have also been shown to strongly affect organizational structure, no matter what technologies are employed.[7] It is also likely that the culture in which an organization is embedded will affect the relationship between technology and organizational structure. One study of manufacturing plants in Britain, France, and Germany found that the relationship between technology and organizational structure found by Woodward did not hold when a cross-national analysis was undertaken. No matter what the level of technological complexity, German firms had higher levels of worker expertise, autonomy, and flexibility than French firms, while British firms were in an intermediate position. In similar fashion, a study of American and Japanese factories found that there was less specialization and taller hierarchies in the Japanese firms even when the technologies used were substantially identical to the ones employed in the American factories.[8]

Although a fair number of studies have examined the relationship between technology and organizational structure, they have not formed a coherent whole because individual researchers have focused on different organizational levels, selected different sets of variables, and employed idiosyncratic definitions of technology. And yet, for all of the deficiencies of this research enterprise, it has led to a significant rethinking of the nature of organizations and their management. As the idea took hold that an organization's structure was influenced by the technology it employed, it became apparent that one of the cherished notions of management, that there is "one best way" to organize things, is incorrect. What works with one production technology will not necessarily work with another. Although the research results have been mixed, their general thrust seems to indicate that in order to be successful an organization needs to develop and use organizational structures and processes that are appropriate for the technologies it employs.

Technology as a Consequence of Organizational Structure

Up to now we have considered how technology affects organizations. Yet the reverse can also be true. Organizations can shape technological change through their ability to affect the supply and demand for a particular technology. We are a long way from Adam Smith's perfect market, where no individual firm is able to significantly influence the supply of a product or the demand for it. In regard to supply, an organization that accounts for a significant portion of an industry can strongly influence the technological development of the industry as a whole when it creates (or refrains from creating) new products. The choices of a few firms thus determine the kinds of cars we drive, the way steel is made, and the operating systems used by our personal computers. In similar fashion, when a few organizations are the major purchasers of particular products (as when a few aerospace firms buy highly specialized machine tools), their requirements will determine the nature of the product and the technology it embodies.

On what basis do organizations make technological choices? This is an important question, given the importance of organizational decisions for the course of technological change. Unfortunately, researchers have not paid much attention to this issue. Most of the studies centering on the connection between an organization's technology and its structure simply take technology as a given. In the studies

just summarized, the technologies used by organizations appeared as independent entities. The implication of these studies is that organizations and their personnel react passively to the presumed dictates of technology.

It is possible, however, that the technologies employed by an organization are themselves the product of the organization's own structure and processes, and in particular, the configurations of power within the organization. Such a view would be in general accord with the perspective presented earlier in this book, that technologies can be, and often are, employed by individuals or groups in order to advance their own interests. Charles Perrow, whose theory was described, has recognized this, and in so doing has expressed some disenchantment with his earlier work in which he took technology to be an independent influence on an organization's structure. Perrow forcefully makes the point that, after all is said and done, organizations are powerful tools for achieving goals. Much therefore depends on who controls the tools, and for what purposes.[9] A technology might be selected not because of its innate superiority, but because it meets the needs of the power holders within that organization.

One example of this process can be found in the early history of electrical power in the United States.[10] Until 1915 the most common sources of electrical power were small-scale generating plants that had been set up to serve individual homes, apartment buildings, or business enterprises. In the years that followed, these facilities went into decline as large generating stations serving a wide area came to be the dominant mode of generating electrical power. Some of the success of these stations can be attributed to more efficient operation through economies of scale, but more was involved than the pursuit of efficiency. Of considerable importance to the shaping of the American electrical power industry were two industry-wide organizations, the National Electric Light Association (NELA) and the Association of Edison Illuminating Companies (AEIC). These organizations were in turn strongly influenced by a few men who had close personal and organizational ties to Samuel Insull, the entrepreneur who played the leading role in the construction and operation of large-scale urban generating plants. Insull's associates used their strategic position within NELA and AEIC to determine the kinds of topics discussed at meetings of the two associations and the papers they published, and to take the lead in prescribing the equipment and procedures deemed best for the industry. Most importantly, the group was able to strongly influence the drafting of government regulations that worked to the advantage of privately owned, centralized generating plants, and to the detriment of local, small-scale facilities. In sum, the basic technological configuration of electricity generation was not solely the result of technical and economic requirements, but also reflected the use of organizational power to advance the interests of particular individuals and firms.

Another noteworthy example of the choice of technology being affected by the exercise of power in an organizational setting is provided by David Noble's study of the development of numerically controlled machine tools.[11] During the early 1950s the Servomechanism Laboratory at the Massachusetts Institute of Technology, with the financial suport of the U.S. Air Force, produced the first

numerically controlled (NC) machine tools. Instead of being manipulated by skilled machinists, these devices were guided by programs stored on magnetic tape. NC technology increased productivity and allowed the precise machining of the complex shapes used in modern aircraft. At the same time, NC machine tools significantly reduced the amount of skilled labor required, and removed a great deal of decision-making power from the machinists. These consequences could be taken as an unavoidable by-product of technological advance; that is, the technology determined the skills, work patterns, and hierarchical relationships found in a machine shop using NC machine tools.

The actual story is quite a bit more complicated. In the first place, the use of numerical control was not the only way to make machine tools run automatically. During the late 1940s a "record-playback" method for machine-tool guidance was developed. This technology recorded the motions of a machinist as he made a part. These motions were recorded on magnetic tape, which was then used to run the machine tool. The machinist, and not a programmer removed from the workplace, was thus the source of the machine's instructions. As it turned out, this was the greatest drawback of this technology. Numerical control was far more appealing to managers because it allowed them to gain more control over the work process. NC tools promised a reduction of the decision-making powers of workers, and vested it with managers, engineers, and programmers. In the words of one manager, "Look, with record-playback the control of the machine rests with the machinist—control of feeds, speeds, number of cuts, output; with NC there is a shift of control to management. Management is no longer dependent upon the operator and can thus optimize the use of their machines. With NC, control over the process is placed firmly in the hands of management—and why shouldn't we have it?"[12]

As things turned out, NC did not completely fulfill management's hopes for greater control. As we have seen in Chapter 9, computer-controlled production systems have their drawbacks, and the fully automated factory is still a long way off. Human machinists are still necessary to keep production going. The programs governing the machine tool often have bugs; machines malfunction; and adjustments have to be made to compensate for tool wear, casting irregularities, and slight elasticity in the material. Machnists can also make important suggestions regarding how the design of a piece can be improved and how it can be more efficiently produced. The absence of regular feedback from the shop floor to the design room can result in considerable waste and inefficiency.[13]

These kinds of issues will take on a growing importance as computers and automated systems are increasingly incorporated into production processes. Modern information systems can be used to enhance the power and responsibilities of shop-floor workers. At the same time, however, they can produce the opposite effect by giving management a greater capacity to centralize operations and restrict the discretion of the workers. As one manager asserted, "The more we can control with the computer, the less dependence we will have on operators with in-depth knowledge. When there is a problem, we will have computer programs, logic, electronic sensors. We will be able to understand the problems."[14]

A certain degree of computer-based centralization may be justified in terms of its supposed contribution to coordination and efficiency. But this is hardly its only rationale. Many managers worry that computerized information systems can just as easily promote decentralization by making information more readily available to ordinary workers. A top executive from the same firm as the manager quoted above noted:[15]

> The classic managerial role has been that of the handler, manipulator, dealer, and withholder of information. An issue that the technology is forcing us to face involves the loss of managerial control. . . . Suddenly you are vesting in folks at the control station, folks who are interfacing with a tremendous technology power—power to see all the functions of the operation. That is kind of scary to some managers.

Managers realize that the control of information has been an essential element of their authority. Consequently, in the words of one line manager, "Managers perceive workers who have information as a threat. They are afraid of not being the 'expert.' They are used to having everyone come to them and ask what to do."[16] This use of information was duly noted by a worker in the same firm: "[Managers] can't share information with us, because only by holding on to knowledge that we don't have can they maintain their superiority and their ability to order us around."[17]

In this setting, computer-based information systems are not neutral instruments, but are likely to be used in ways that are congenial to those occupying positions of authority within organizations. As with NC machine tools, a technology may be employed because managers see it as a way of extending their own power. Conversely, computerized information systems may be used to empower workers, enhance their responsibilities, and give them a claim to higher wages. There is no simple technological logic governing the use of these systems. The use of an existing technology may reflect the existing distribution of power in an organization, while the installation of a new technology may become an occasion for conflict over how it will be wielded in the future.

Organizations and New Information Technologies

Some of the issues surrounding the relationship between technological change and the evolution of organizational structures appear in sharper focus when we take a look at electronic information technologies. Numerous scholars have pointed out that the essential work of organizations centers on the manipulation of information, broadly construed. Whether it is within an employment office, a bank, or a school, members of an organization spend a great deal of their time gathering data, analyzing it, deciding what to do in the light of what they have learned, communicating with others, and evaluating and reporting what has been done.

During the second half of the nineteenth century, organizations were able to expand, improve their operations, and operate at higher levels of efficiency and effectiveness through the use of what were then novel technologies for gathering, recording, analyzing, distributing, and storing information—typewriters, telegraphs, dictating machines, telephones, pneumatic tubes, standardized forms, carbon

paper, and filing systems.[18] Recent decades have seen more revolutionary changes in information technology, and few of today's organizations can get along without computers, database management programs, word processing, spreadsheets, fax machines, the internet, e-mail, photocopy machines, and voice mail, while growing numbers of organizations are making extensive use of more recently introduced technologies like intranets for internal communications and videoconferencing for linking participants from all over the globe in real time.

The nearly universal use of electronic information technologies has motivated a substantial number of researchers to conduct inquiries into how these technologies have affected the structure and functioning of contemporary organizations. In general, this research has indicated that advanced information technologies have speeded up operations, reduced costs, increased the amount and accessibility of information, and more extensively linked members of organizations.[19] Less certain, however, are the effects of new information technologies on organizational structures and procedures. As with all significant technological advances, there is rarely a simple, straightforward connection between technological and organizational changes. A new information technology, no matter how radical, is only one of many influences on a particular organization, and not necessarily the most important one; other organizational features, such as size, the composition of the work force, and the nature of the clientele may be more significant than the information technologies in use.

One much-discussed issue has to do with the role of new information technologies in promoting organizational decentralization. As some students of organizations have argued, a primary reason for the concentration of organizational authority in times past was the difficulty of obtaining and analyzing information. Information was a scarce resource, something that could be provided for only a few members of an organization, those at the top of the managerial pyramid. In similar fashion, only those at the summit of the organization were deemed capable of intelligently acting on the information made available to them. In contrast, today's electronic technologies make information and the ability to analyze it readily available at low cost, allowing more decentralized and participatory modes of decision-making.

If this were indeed the case, we would have a clear-cut example of technological determinism. But as has been noted before, the way that many technologies are actually employed often has more to do with existing distributions of power and authority than with presumed technological imperatives. Instead of democratizing the workplace, it has been argued that network-based technologies may be used to enhance managerial control.[20] As we have already seen, some new workplace technologies, far from empowering workers, may enhance top-down control through the use of electronic monitoring.[21] To take another example, it has sometimes been stated that the use of e-mail has eroded organizational hierarchies by allowing direct communications between the upper and lower ranks. This may come to pass when the top organizational echelons value and encourage bottom-up communications, but many managers would prefer to avoid such "distractions." Again, a great

deal depends on what the members of the organization, especially the managerial cadre, want to do with new communications technologies. The variability of managerial response to electronic communications probably is one of the main reasons that attempts to link the use of e-mail with organizational decentralization have not produced conclusive results.[22]

As a final point, it should be kept in mind that new communications technologies do not necessarily supplant existing ones. For example, it might be expected that the growing use of the telephone in the early twentieth century reduced the need for traditional forms of communication, but in fact the opposite occurred, as telephone use seems to have stimulated the desire for more face-to-face communication, not less.[23] The same thing may be happening today. New electronic media such as e-mail and videoconferencing certainly have their place, but they fail to provide some crucial elements of communication, such as body language and indications of whose turn it is to speak. Old-fashioned, face-to-face communication may not be of much importance for many organizational tasks, but it is usually essential for activities that have an important social-psychological component, such as negotiating, maintaining relationships, and building trust.[24]

Interorganizational Relations and Technological Development

No business firm, no matter how large, develops all of the technologies that are embodied in its products. Every firm depends on a network of suppliers for the new materials, components, and even the ideas that are incorporated into its own products.[25] This is especially true of mature industries, where supplier firms are likely to be the principal source of substantial technological breakthroughs.[26] Without the efforts of outside suppliers to develop and sell innovative products it is likely that the technological level of many established industries' products would stagnate. Technological changes are therefore shaped not only by the structure and dynamics of individual organizations, but also by the pattern of relationships between organizations.

The automobile industry exemplifies the transfer of technology from supplier organizations to the automobile manufacturers themselves. It also demonstrates that interorganizational relationships may act as obstacles to technological advance within the industry. From its earliest years, the automobile industry has depended on thousands of outside suppliers for many of its components—everything from nuts and bolts to complete engines. These suppliers have provided some of the most important technological innovations for the automobile: disc brakes, radial tires, fuel injection, and electronic ignition, to name but a few. These innovations did not sell themselves, however. Before they appeared in automobiles they had to be bought by the automobile manufacturers (also known as "OEMs," or original equipment manufacturers).

Throughout most of the history of the industry, the relationship between suppliers and OEMs was that of independent buyers and sellers; cooperative approaches were generally absent. Suppliers were often left in the dark about the actual application of their products; a supplier might not even know which cars used its products or that they were about to be replaced by something totally