Chapter 4

Technological and Organizational Change: Implications for Training

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Chapter 4

Technological and Organizational Change: Implications for Training

SUMMARY

When surveyed in mid-1990, half of a group of 401 U.S. firms reported that poor worker skills and motivation hurt their ability to deliver high-quality goods and services.[1] To improve employee morale and create positive attitudes toward quality and customer service, companies are reorganizing their workplaces—for instance, by introducing multi-skilled work groups with self-management responsibility. This trend, together with a second—the spread of decentralized computing-is reshaping the American workplace. To function effectively in the new environment, employees need adequate basic skills, competence in interpersonal relations and communication, and a relatively broad range of task-specific skills.

Computers and related information processing technologies accounted for nearly half of U.S. spending on capital equipment in 1989.[2] As PCs, terminals, and keypads appear on more and more desks and work stations, employees must be able to read from them, enter data, interpret prompts, help screens, and job aids. In automobile plants and textile mills, banks and department stores, more employees will be expected to make decisions and take action on their own initiative.

Some of these people will need relatively advanced technical skills-for weighing alternative production schedules, debugging programs for numerically controlled machine tools, or distinguishing between faulty instrument readings and a production process that has gone out of control. Others will have to take greater responsibility for their work: for inspection and quality control; for routine maintenance, simple troubleshooting, and ad hoc problem solving; for dealing with other departments, and perhaps with customers.

These skills can be hard to transmit, harder to evaluate. It becomes more difficult to trace success or failure on the shop floor or in the back office of a bank to particular individuals. But these are the skills that U.S. industry will need in order to be competitive. Not all employees must have them, but the direction of change seems clear: mental skills increasingly stand alongside manual skills, sometimes replace them; more jobs will require good social skills, not only because of the greater importance of working in groups, but because of the growth of service jobs that place employees in contact with customers.

Although changing workplace practices have been heavily publicized, some firms continue to pay more attention to investments in capital equipment than to investments in human capital and organizational restructuring. Nothing illustrates this better than the failure of General Motors (GM) to benefit more substantially from its investments in plant and equipment during the 1980s (table 4-l). While many other factors influenced the productivity figures shown in the table, ranging from labor relations to product mix and designs suited for efficient manufacturing, the simple fact is that GM was unable to utilize its plant and equipment as effectively as its competitors, for reasons that more than likely lie in organization and management of production.

[1] "Higher Wages Not Major Factor Holding Back U.S. Competitiveness, Business Survey Finds," ***International Trade Reporter,*** **July 11, 1990, p. 1077. Seventy percent of these companies, surveyed by the Gallup organization, had more than 500 employees.**

In another survey, managers rated employee training and motivation as the most important factor for improving the competitiveness of U.S. manufacturing. At the same time, their responses to other questions revealed that many, particularly in small and medium-sized firms, had no more than a hazy idea of how to go about improving either training or motivation. This survey, conducted by Ernst & Young, is summarized in Lawrence T. Michaels, "Priorities for Obtaining Competitive Advantage through Manufacturing," paper presented at Autofact '89 Conference& Exposition Detroit, MI, Oct. 30-Nov. 2, 1989.

[2] ***Dun & Bradstreet Comments on the Economy,*** **April/May 1990, p. 2.**

Table 4-l —Investment by U.S. Automobile Producers and Productivity Improvement, 1979-89

	General Motors	Ford	Chrysler
Investment in plant and equipment (billions of dollars)	$72.6'	$41.2	$22.5
Investment per vehicle produced	$920"	$680	$1,090
Change in labor productivity:			
Engines	-13%	43%	9%
Stamping	14	45	30
Vehicle assembly	5	31	19

a,979-1988.
SOURCES: Investment-annual reports. Productivity-Bruce Beier and Mary Gearhart, "Productivity Vs. Profit Sharing," *Automotive Industries,* April 1990, pp. 53-56, based on *The Harbour Report: A Decade Later.*

In fact, few of the trends outlined in this chapter have as yet penetrated very deeply into U.S. industry.[3] Some American firms have moved decisively to implement new forms of work organization. Others are experimenting with statistical process control (SPC) or just-in-time (JIT) production without understanding that these are techniques for aiding in reorganization as much as ends in themselves.

Some of the new practices had earlier been exported from the United States to Japan (SPC is perhaps the best known example). In emulating these and other features of Japanese production systems, American firms are not only chasing moving targets with no assurance of catching up, they are, in some cases, adopting features selectively—and hoping that a system with only some of the parts in place will function acceptably.

The striking contrasts between U.S. and Japanese production systems lie, not in the equipment on the factory floor, but in how companies manage and train their people, allocate tasks to individuals, to work groups, and to automated machinery. Most Japanese managers realize that training must be an integral part of strategies for automation. Most American managers do not. When managers treat their workforce as an adjunct to "technology," as many still do, they fail to capitalize on employee skills, to reap the rewards that can come from blue-collar innovation (alongside the white-collar innovation that comes from technical and professional workers).

How far will the new practices outlined in this chapter eventually spread? The limits will be tested when restructuring bumps up against adversarial traditions of labor-management relations. In Japan, labor is weak, the workforce docile; management techniques that would be viewed as coercive in the United States have been common. On the other hand, the no-layoff policies of Japan's large corporations provide a level of employment security seldom approached here. Will American firms emulate this aspect of the Japanese system? Successful reorganization and restructuring depends on workers who view themselves as part of a more-or-less professional undertaking, one tied at providing value to the firm's customers. Such beliefs will not last long if companies respond to the next recession with immediate layoffs. It is one thing to treat and train ordinary workers as professionals, or at least try to convince employees that the company views them this way. It is another thing to pay them when there is no work to do.

PRESSURES FOR CHANGE

The skills and training required of shopfloor employees have changed a good deal over the past two decades.[4] Technological change-notably the computer in the workplace-is part of the reason. But it is new technology as reflected in the redesign and reorganization of work, more than simply new

[3] Thirteen percent of American firms responding t. a survey in early 1990 were using some form of self-managed work group, with another 4percent reporting plans to move in this direction. ''Workforce 2000—Competing in a Seller's Market: Is Corporate American Prepared? A Survey Report on Corporate Responses to Demographic and Labor Force Trends," Towers Perrin and Hudson Institute, July 1990, p. 27. This survey covered 645 companies, in both manufacturing and the servicesBecause most of the responding companies were relatively large, and large companies have been in the lead in adopting work groups, these percentages probably should be regarded as upper bounds.

[4] This chapter draws heavily on "Corporate Strategy and Industrial T raining," report prepared for OTA under contract No. L3-5240 by Robert R. Miller, Feb. 28, 1990. Interviews and plant visits for thatreport, and by OTA staff, underlie much of the discussion that follows.

machines or processes, that creates new needs for training. (In this chapter, work organization refers to the design and management of the production process, with the more inclusive term restructuring reserved for the enterprise and its strategy as a whole.)

In earlier years, most training had a simple function: to teach unskilled or semiskilled workers how to perform specific tasks and operate particular pieces of equipment. Today, companies put more emphasis on flexibility and adaptability; they seek workers who can master a variety of tasks. In many redesigned production systems, people work in groups; collectively, the group takes over some of the responsibilities earlier vested in first-line supervisors (foremen), and some of the tasks once the province of grey-collar technicians and maintenance workers. By replacing some of their skilled workers, companies not only save money, but gain flexibility: group members can rotate from one job to another, help each other out, fill in for absentees. Workers must have the social and communications skills to fit into the group and contribute. For such reasons, firms seeking to implement new competitive strategies based on new forms of work organization typically find they must modify their approach to hiring as well as to training.

Computers and computer-based equipment also require new and different skills-whether they are part of highly automated systems, or when simply used as adjuncts to traditional plants and processes.[5] Nonetheless, it is the changing context for work that puts the greatest demands on trainers and on managers and supervisors. Work reorganization forces lower level employees to take more responsibility, sometimes including self-supervision and group supervision, cooperate more closely with one another, understand their place in the production system and in the organization. This can be unsettling for some people, including first-line supervisors—who may in fact find their jobs vanishing. Responsibilities broaden. So do skills. People are less likely to be pinned down by a narrow job classification.[6] Reorganization calls for somewhat more technical training, but most of all for new forms of behavior. Much of the training is indirect, embodied, for instance, in courses in SPC or JIT. In manufacturing, the forces driving these changes stem largely from international competition. In the services, they stem primarily from domestic competition.

As they pay more attention to training, managers find themselves paying more attention to the costs of training. When most worker-level training was one-on-one in the factory or the office, the costs were buried, while the only measure of effectiveness was whether new employees learned to perform their assigned tasks. Today, more companies view training as a cost center, work harder to contain costs and measure effectiveness.[7]

Globalization

With imports and exports growing faster than the economy itself, more American goods and services face foreign competition each year. Globalization, a trend that goes well beyond simply investing in foreign subsidiaries for production and distribution, accelerated markedly during the 1980s. The objective: to combine and integrate operations in the major industrial nations. Often, this involves decentralization, with such functions as design, development, manufacturing, distribution, and marketing located in different parts of the world. Instead of first developing products for home markets, and then, if these prove successful, moving abroad, companies now design products for world markets, modifying them only slightly for different countries. New products may be simultaneously introduced in Japan, Europe, the United States, and elsewhere.

To compete in this environment, American firms must control costs and raise quality (ch. 3). They must also build more flexible organizations, able to provide the variety that consumers now expect and the just-in-time deliveries demanded by corporate

5When Martin Marietta adopted MRP 2 (Material Review Planning (sic)), a computerized method for production planning and control, the company spent five times as much on training as on the hardware and software required. William B. Scott, "Aerospace/Defense Firms See Preliminary Results From Application of TQM Concepts," ***Aviation Week & Space Technology,*** **January 8, 1990, pp. 61-63.**

6Automobile plants operated by the major U.S. producers have traditionally had large numbers of job classifications—80-95—with strict rules governing who could do what. Some ''transplants' '—U.S. factories operated by Japanese automakers-have only two classifications, for production workers and maintenance staff; none has more than four. ***Foreign Investment.' Growing Japanese Presence in the U.S. Auto Industry, GAO/NSLAD-88-111*** **(Washington DC: U.S. General Accounting Office, March 1988), p. 52.**

7In 1985, IBM conducted a corporate-wide study of training expenses, finding they totaled $900 million exclusive of lost work time—50 percent more than expected. Over the next 2 years, the company cut $150 million from its education/training budget. Ralph E. Grubb, Academy for Educational Development personal communication% May 11, 1990.

customers. Multinationals are both expanding and decentralizing, while seeking alliances with customers, with putative rivals, and with suppliers. Firms are simultaneously integrating globally and disintegrating by farming out more production, contracting for services once provided internally, and pursuing joint ventures and other intercorporate linkages (e.g., cooperative R&D and technology development). Truly international corporations have begun to emerge-IBM and Citibank, Sony and Honda. Although the notion of a rootless multinational remains an exaggeration, borders have less significance for many companies today than in the 1970s. Globalization means that American plants will have to achieve overall productivity levels superior to those abroad, else lose work to overseas locations with lower costs, superior quality, or quicker and more responsive customer service.[8]

The Japanese Approach to Production

Japanese companies have been highly visible in the United States, first as exporters, and more recently through direct investments in onshore plants. Both American and European managers have been forced to rethink their global strategies, especially in production. Japan's prowess in manufacturing has particular significance for training. Success in producing high-quality goods at low cost—computer chips or supertankers-stems from highly developed production systems that effectively couple product and process design, work organization, and shopfloor management. The better workers know their jobs and understand their role in the system, the better the system will function.

In automobile assembly, the best Japanese production systems have been termed "lean" because they attempt to minimize buffers of work-in-process (WIP) inventory that might obscure production problems and slow their resolution.[9] These systems depend heavily on employees trained to avoid rather than detect and correct product defects.

Even more than in the textile examples in chapter 3 (box 3-A), mistakes by shopfloor workers in an automobile plant can be disruptive and costly. With little backup, one mistake can shut down an entire line, idling dozens of workers. Japanese firms not only accept the risks of such systems, they exploit them to cut labor and inventory costs to a minimum, keep the system under control, and keep the pressure on the workforce.

Lean systems require skilled, flexible, and motivated workers to anticipate possible problems, eliminate bottlenecks and production shutdowns, ensure quality. Training plays an intrinsic role in terms of motivation as well as for transmitting concrete skills. These systems also depend on products designed for ease and speed in manufacturing, and on a management style stressing employee involvement and job rotation. Work groups, *kaizen* (continuous improvement) programs, and quality circles are common. Among other functions, these help create communications channels between the factory floor and engineering to achieve true design-for-manufacturability.

In contrast, the "robust" systems common in U.S.-owned auto plants rely on large inventory buffers as safeguards against unforeseen events (e.g., machinery breakdowns, late delivery of parts). In robust systems, workers typically have relatively tightly defined task responsibilities, few engineers spend time on the factory floor, and organizational barriers impede the flow of ideas between product design and manufacturing engineering, as well as between the shop floor and engineering.

Lean systems attempt to avoid problems, robust systems to guard against their consequences. On the evidence of plant performance, lean systems perform better, exhibiting higher levels of both productivity and product quality than the robust systems

8With the spread of automation, direct labor cost has become less important in decisions on location. At Tandy Corp.'s Fort Worth, TX, plant, direct labor accounts for less than 2 percent of the cost of each PC produced. "North American Profiles,' *Datamation*, June 15, 1990, p. 67. In automobile production, direct labor now comes to about 10 percent of total costs, indirect labor (including management) adding another 15 percent. Bruce Beier and Mary Gearhart, "Productivity Vs. Profit Sharing," *Automotive Industries*, April 1990, pp. 53-56. But if the relatively high wage levels of U.S. production workers serve as less of a handicap, competition to control indirect costs will be no less fierce.

9John F. Krafcik, "Triumph of the Lean Production System," *Sloan Management Review*, Fall 1988, pp. 41-52. Also see Haruo Shimada, "Japanese Management of Auto Production in the United States: An Overview of 'Humanware Technology'," *Japanese Investment in the United States: Should We Be Concerned?* Kozo Yamamura (cd.) (Seattle, WA: Society for Japanese Studies, 1989), pp. 183-205.

Photo credit: Diamond-Star Motors Corp.

Automated welding of automobile bodies.

favored by American firms.[10] Indeed, productivity, quality, automation, and training are found together in the best-performing auto plants—in U.S. transplants as well as in Japan. Honda, Nissan, and Toyota give their American workers substantially more training than do American automobile manufacturers (box l-B, ch. 1), and achieve higher productivity levels. The transplants, moreover, seem to be operating at quality levels slightly better than sister plants in Japan.

In effect, the production systems developed by Japanese automakers combine work organization built around semi-autonomous groups with substantial training and careful attention to shopfloor management to achieve outstanding quality and productivity. Nonetheless, while making some changes in work organization in some plants (GM calls its version of JIT synchronous production), the American automakers continue to operate traditional, robust assembly plants, and, as figures 1-1 and 1-2 showed (ch. 1), provide relatively little training. Even so, some American firms have begun imitating some aspects of Japanese production systems. GM, for instance, invested in its joint venture with Toyota, NUMMI (New United Motors Manufacturing Inc., Fremont, California) with the explicit intent of learning from its partner's approach to shopfloor organization and management.

In the automobile industry, and in many others, American firms have also emulated Japanese practices by reducing the ranks of their suppliers, and seeking closer working relationships with the most capable of them (see box 4-A). Stable, long-term links with a relatively small group of frost-tier suppliers help keep the overall chain of production flexible, responsive, and well controlled, much as JIT production helps isolate defects and other systemic problems within a given plant. Xerox now buys from fewer than 500 suppliers, compared with 5000 a decade ago. As major American corporations continue to emulate Japanese production strategies, their suppliers will have to revamp their own production systems—and in many cases retrain their employees-or lose business to more nimble rivals, some of them foreign-owned.

WORKPLACE ORGANIZATION AND MANAGEMENT

Old and New Approaches

The design of most U.S. production systems continues to reflect the scientific management paradigm descending from Frederick Taylor, whose book on the subject appeared in 1911.[11] Particularly in labor-intensive mass production of consumer goods (automobiles, apparel, appliances), unskilled workers have been assigned to a particular work station—tied to a machine, or to one position on an assembly line. Their job: to repeatedly carry out a single task or a short sequence of simple tasks. Specialists designed the work. Foremen oversaw it. Large inventories between stations and lines provided "robust' protection against disruptions that might stop the flow of production. Inspectors

[10] ''Training and the Auto Industry: International Comparisons,' ' report prepared for OTA under contract No. N3-1910 by John F. Krafcik, Competitive Manufacturing Research, February 1990. This report summarizes results of surveys conducted by MIT's International Motor Vehicle Program, most of them in 1988, covering 45 automobile assembly plants. The 45 plants included 12 in the United States operated by U.S. automakers, 8 in Japan operated by Japanese firms, and 3 transplants operated by Japanese automakers in the United States. (Most of the 22 others were in Europe.) Also see John F. Krafcik and John Paul MacDuffie, "Explaining High Performance Manufacturing: The International Automotive Assembly Plant Study," International Motor Vehicle Policy Forum, Massachusetts Institute of Technology, May 1989; and John Krafcik and John Paul MacDuffie, "Effect of Design Manufacturability on Productivity and Quality: An Update of the IMVP Assembly Plant Study," International Motor Vehicle Policy Forum, Massachusetts Institute of Technology, January 1990. Comparisons of design-for-manufacturability in the latter study found Japanese automakers ranking high, with two of the three major U.S. producers in the bottom half of all firms surveyed.

[11] Frederick W. Taylor, *The Principles of Scientific Management* (New York: Harper & Brothers, 1911).

Box 4-A-OEM-Supplier Relationships

OEMs, or original equipment manufacturers, buy raw materials, parts, components, and subassemblies from other firms. Automakers, for instance, purchase steel, glass, plastic resins, and paint. They also buy carpeting and trim materials, catalytic converters and air bag systems, microprocessors and fuel-injection nozzles. Seeking to match Japanese standards of cost and quality, American OEMs are trying to integrate suppliers more fully into their own operations.

The process begins with technical requirements and specifications developed by the OEM's engineering department. "Buyers" then solicit bids and select suppliers. Until a few years ago, the buyer's job was well-structured, much of the work relatively routine-a matter of soliciting bids, managing the selection process, processing contracts, orders, and invoices. While the purchasing department had to know which firms promised to be reliable, monitor those chosen, and help solve delivery and quality problems as they arose, bids were evaluated primarily on costs. (Excess capacity during the 1980s made it particularly easy for automakers to play vendors off against one another.)

Today, the selection process is changing. Price remains important, but competitive bidding has been de-emphasized. In evaluating prospective suppliers, OEMs examine their history of providing consistently high-quality products, and often their internal engineering capabilities. Candidates may be asked to conduct self-assessments and provide detailed information on cost structures, quality control procedures, factory equipment, and workforce capabilities. The OEM may inspect each candidate's plant.[2]

If they pass the initial screening, suppliers become candidates for long-term contracts, perhaps on a sole-source basis; in the automotive industry, such arrangements might extend over a 5-year model run or longer. Suppliers can expect a steady flow of orders so long as their shipments meet the OEM's quality and JIT delivery targets (suppliers may be expected to provide just-in-time deliveries in small lots several times per day). The OEM may consult them at an early stage in the design of new products, ask the supplier's own engineers to take over or share in development work, and stand ready to make modifications during production. Parker-Hannifin, for example, a major producer of hose assemblies for automotive air conditioners, now designs many of these assemblies; in earlier years, OEMs provided Parker-Hannifin with detailed drawings and specifications. Major U.S. automakers have asked suppliers to install computer-aided design equipment compatible with their own to speed exchanges of technical information.

For the OEM, dealing with a smaller group of more broadly capable vendors promises reductions in the upfront cost and time of product development; the OEM shifts some of the risks of development to suppliers (the product may not sell, and the supplier may lose its investment in design, in worker training, even in new production equipment). More important, OEMs hope that common interests will motivate their suppliers to work harder to meet cost, quality, and delivery goals. In return, the suppliers get implicit or explicit guarantees of future sales, with monitoring by the OEM replacing repeated bidding. Pressure to reduce costs has been replaced by pressure to provide JIT delivery and ensure quality (so the OEM does not have to inspect 100 percent of incoming goods). Although OEMs now find themselves helping suppliers with technical problems, few offer direct assistance in training beyond providing materials (e.g., manuals, videotapes).[3]

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[1]Original equipment manufacturers, or OEMs, sell end products—e.g., cars, computers, airplanes. Caterpillar, for instance, offers a broad range of construction equipment as an OEM. It purchases many parts from its own suppliers, and also sells diesel engines as a supplier to builders of heavy trucks.

The discussion in this box is based on "Corporate Strategy and Industrial Training," report prepared for OTA under contract No. L3-5240 by Robert R. Miller, Feb. 28, 1990, pp. 12-14; and "Supplier Relationships and Training, report prepared for OTA under contract No. L3-2850 by Louis G. Tornatzky, Rocco DePietro, and James Jacobs, The Industrial Technology Institute, Ann Arbor, MI, Dec. 15, 1989. Also see *Foreign Investment: Growing Japanese Presence in the U.S. Auto Industry*, GAO/NSIAD-88-111 (Washington, DC: U.S. General Accounting Office, March 1988); and David N. Burt, "Managing Suppliers Up to Speed," *Harvard Business Review*, July-August 1989, pp. 127-135.

[2]Japanese-owned subsidies in the United States put particular stress on quality. In a recent survey, 62 percent of transplant respondents (engineers and managers in Japanese-owned automobile plants, more than half of them Americans) ranked quality as the most important factor in purchased components, while 83 percent viewed a comprehensive SPC program as the most important criterion for chosing suppliers. Daniel J. Holt, "Selling to the Transplants," *Automotive Engineering*, April 1990, p. 8.

[3]In 1985, Ford spun off an in-house training and technical assistance group to form the not-for-profit American Supplier Institute, which now sells services to all comers. The Institute specializes in quality control practices, and has become perhaps the best-known U.S. apostle of Taguchi methods-a set of techniques that stress life cycle quality, reliability, and customer satisfaction. For a nontechnical introduction see Genichi Taguchi and Don Clausing, "Robust Quality," *Harvard Business Review*, January-February 1990, pp. 65-75.

Many smaller suppliers have had trouble meeting the new requirements. Surveys reveal sharply differing perceptions among OEMs and suppliers concerning the need for such manufacturing practices as JIT, SPC, and *kaizen* (continuous improvement), with suppliers uninformed or negative compared with OEMs.[4] Such findings suggest that, on the whole, movement towards more streamlined supplier networks will be relatively slow in the United States. They also suggest that many small and medium-sized manufacturing firms, at sea amidst the confusing choices posed by an array of new technologies, shopfloor practices, and customers seeking more responsive service, will have trouble surviving. These companies will have to reorganize their own production operations or look for less demanding customers. Over the next decade or two, thousands of such firms will probably be bought out or merged. Others will simply shut their doors.

[4]A recent Delphi survey conducted by Andersen Consulting with 288 respondents from vehicle manufactures and 431 from suppliers, found wide agreement (90 percent) on the importance of structured programs for continuous improvement such as *kaizen*. But few respondents from the supplier group placed much weight on JIT, *kanban*, and similar production practices—even though these are necessary tools, goals, and yardsticks for measuring progress in any continuous improvement effort. In another indication of the relatively slow pace of change in the motor vehicle and parts industry, Andersen's Delphi panels have seen JIT as a constant 2-3 years in the future ever since the early 1980s. Peter C. Van Hull, "Results of 1989 Survey of Automobile Trends: Putting the Pieces Together," paper presented at Autofact '89 Conference & Exposition Detroit, Oct. 30-Nov. 2, 1989, summarizing Andersen's proprietary report.

checked quality at various points. Supervisors called in technicians or maintenance workers to handle problems as they arose.

In these traditional production systems, unskilled workers might need some minimum level of manual dexterity, but the work was more likely to be boringly repetitive than technically demanding. Grey-collar employees—toolmakers, electricians, machine repairers-analyzed problems, exercised judgment, made decisions. So did supervisors and manufacturing engineers. But not ordinary workers. Particularly in unionized plants, the tasks each employee could do were tightly circumscribed by a plethora of work rules.

The era of mass production is not over, but work reorganization together with flexible automation (discussed in app. 4-A, at the end of the chapter) has made shorter production runs economical, and encouraged product differentiation. In assembly, where the inroads of automation have been slow, more companies have turned to work groups to improve quality and flexibility, while reducing the number of first-line supervisors to cut costs. Typically, supervisors have been assigned managerial and liaison tasks earlier exercised at higher levels (e.g., interdepartmental coordination).

Table 4-2 summarizes the primary features found, singly and in various combinations, in redesigned production systems, taking the view that it is the organization of production, not the computer methods summarized in appendix 4-A, that distinguishes the best performing companies. As noted in the table, when work groups replace individual work stations, employees typically need broader skills. Sometimes, shopfloor-workers may even be asked to deal directly with customers (perhaps their counterparts in other fins). Supervision in the traditional sense often recedes, with hourly paid group leaders given responsibility for internal coordination and conflict resolution, as well as liaison with other departments.

Rarely will the production system in any one company include all the characteristics listed in table 4-2. Partial, halting, and piecemeal implementation has been the rule. But many American companies are experimenting with at least some of these steps. This generally calls for three types of training:

1. *Basic skills.* With more employees required to read information from computer terminals and enter data correctly, companies that reorganize as outlined above typically screen employees for competency in reading, writing, and simple arithmetic, followed by refresher courses or intensive instruction for those who need it.
2. *Task-specific technical skills.* Companies seeking a multiskilled workforce must necessarily provide more training in the operation of particular pieces of equipment.
3. ***Organizational training.*** Intended to set each individual's job in overall context, demonstrate its importance for achieving the firm's goals (i.e., cost, quality, customer service), and motivate workers, this kind of training is by far the most difficult to deliver effectively. Companies frequently rely on indirect methods--e. g., training in SPC—to prepare workers to take more responsibility.

Table 4-2—New Job and Organizational Design Practices in U.S. Industry

1. **Seeking flexibility, firms *define jobs more broad/y,* with multiskilled groups often taking over responsibility for a number of tasks. Sometimes broader skills and responsibilities follow more or less directly because computer automation permits each person to do more.**
2. **Training exposes employees to corporate goals and enhances *motivation, sense of belonging, and commitment. These* objectives often merge into the development of the *contextual/ /knowledge* employees need in order to understand how their work affects the rest of the firm and its customers.**
3. **Employees at lower levels maybe granted *a say in decisions on procedures,* and perhaps equipment, as well as day-to-day operations. Often, participation takes the form of consultation between employee representatives and the company's technical and managerial staff.**
4. **Managers may give groups of *workers* some or all of the authority formerly vested in first-line supervisors, including responsibility for quality and for coordination with other departments.**
5. **In selecting new employees, companies may weigh *motivational and attitudinal/ factors,* as well as social and communications skills, more heavily than experience. Some American firms have adopted multiple levels of screening, with aptitude and perhaps psychological tests followed by interviews with both supervisors and prospective co-workers.**
6. ***Pay sea/es* may reflect an employee's skills (pay for skills) and/or performance (payment for results).**
7. **In decentralizing, some companies have replaced functional with *product-centered organizations,* intended to channel work smoothly and directly from input to output of the system, creating a faster, more flexible (through-not necessarily less costly) production process.**

SOURCES: Technology *and Structural* Unemployment: *Reernp/eying* Displaced *Adults,* OTA-ITE-250 (Alexandria, VA: National Technical Information Service, February 1986), pp. 356-357: *International Competition in Services.* OTA-ITE-328 [Washington. DC: U.S. Government Printing Office, July 1987), pp. 278-284. "

Much organizational and motivational training aims to modify attitudes concerning employee responsibility, encourage awareness of the link between workplace tasks and the company's overall success or failure, and build loyalty to the organization. The intent is to persuade people that their jobs are vital for the continuing prosperity of the firm, and that management values their contributions, small or large. Although some of this training smacks of paternalism-and some companies admit this-it should not be viewed solely in that light.

Box 4-B gives examples of two American manufacturers, pressed in different ways by international competition, that have taken some of the steps outlined above. To the extent that cost-benefit tradeoffs can be evaluated, more firms are making careful efforts at measuring them; they are finding that training helps workers learn on the job, that careful attention to integrating new employees into the organization can reduce the time required for them to become fully productive.

New Responsibilities

With work groups taking on self-management responsibility, companies have eliminated foremen, or placed them over several groups (totaling perhaps 80 or 100 employees, rather than a dozen or so). As the number of job classifications declines, production workers also take over some of the responsibilities of technicians and craft workers (e.g., inspection, simple maintenance). Finally, those few plants that have undergone more-or-less complete transitions to work groups have had to change their ''management' information systems in rather fundamental ways. Some have begun transmitting customer orders (and sales projections) directly to the factory floor.

Production Workers

In the United States, management has traditionally given orders and labor has followed them. As once-sharp lines blur, companies call on a loosely

Photo credit: UAW-Chrysler National Training Center

A joint union-management team develops training plans.

Box 4-B—Work Reorganization and Training in U.S. Industry: Two Examples[1]

Motorola: Microprocessor Production

Managers at Motorola pride themselves on their success in taking on Japanese competition, both at home and abroad. A 1988 recipient of the Malcolm Baldridge Quality Award, Motorola was quicker than most U.S. electronics firms to recognize that manufacturing would be critical during future rounds of international competition. The company's managers realized that training had to be part of their plans for improvement in manufacturing, as illustrated by the reorganization of the firm's Austin, Texas, microprocessor plant.

The Austin factory is currently in the midst of a two-stage program to cut costs and improve quality and customer responsiveness. The first stage, largely completed during 1989, entailed a complete redesign of facilities and operations, but little in the way of new capital outlays. During the second stage, Motorola will invest in a new generation of flexible manufacturing equipment. The company believes it makes no sense to automate until the production process is already functioning well. (This is also one of the hallmarks of Japanese manufacturing practice.)

Although cost reduction was a major goal, this could not be achieved simply by cutting direct labor, which accounted for no more than 5 or 6 percent of manufacturing costs. Motorola sought improved quality (fewer bad parts, greater customer satisfaction), shorter delivery times, and greater flexibility-as well as better employee morale-by organizing production around work cells and work groups. Each cell, manned by 6 to perhaps 20 employees, performs a particular set of tasks. Since the plant operates around the clock, the equipment within a cell might be shared by as many as four work groups. The product mix varies, so that different shifts may be making different chips. In the words of one manager: ''The strategy was to make the product mix problem more manageable . . . to inculcate a strong sense of ownership and accountability in which participative management principles could be applied."

There are no foremen in the Austin plant. Instead, group leaders, who are hourly employees, have taken over the supervisory tasks; planning the flow of production based on incoming orders is one of their primary responsibilities. Each group is accountable for its own output quality, for productivity improvements, and for meeting in-plant delivery schedules (e.g., to the next cell). Technicians and engineers have been assigned to work with most of the groups. Group members must be comfortable with SPC, with a constantly changing mix of products, and with frequent product/process changes. Sometimes they must placate angry customers. Computer systems bring business data directly to the factory floor.

When a skills assessment showed that nearly one-third of the existing Austin workforce was weak in reading, writing, and arithmetic—which had not been apparent in the old work environment-Motorola instituted a 300-hour internal basic skills course. Like their counterparts in other firms, Motorola managers would prefer not to spend time and money making up for what they see as deficiencies in the public education system. But, short of culling employees on the basis of present skills-which no company really wants to do-there was little choice but to proceed with remedial education.

With the first phase of reorganization largely complete, a plant that had been approaching capacity at some 1.5 million microprocessors monthly now produces more than 4 million. Direct labor has been reduced by half, and on-time delivery performance greatly improved. Quality has increased steadily toward the firm's ''six sigma" goal of near-zero defects. Additional training will be required during the second phase, when sophisticated new equipment is installed.

Caterpillar: Heavy Industry in Trouble

In many countries, Caterpillar's familiar yellow earthmoving and construction equipment has traditionally held more than half the market, but in the early 1980s the firm's position came under severe attack. First, Japan's Komatsu expanded its product range far beyond the lower end of the market and into Caterpillar (CAT) territory. Komatsu moved aggressively into Far Eastern countries, and began lining up dealers in the United States. Next, the exchange rate moved against CAT. With the dollar gaining some 40 or 50 percent against major currencies, and much of its production in U.S. plants, CAT found itself in a severe cost-price squeeze. Finally, U.S. contractors, loyal Caterpillar customers, were steadily losing their dominance of international construction markets.

(continued on next page)

[1]''Corporate Strategy and Industrial Training,'' report prepared for OTA under contract No. I-3-5240 by Robert R. Miller, Feb. 28, 1990. Also Robert L. Rose," Caterpillar Sees Gains In Efficiency Imperiled by Strength of Dollar,'*Wall Street Journal*, Apr. 6, 1990, pp. Al, All; Nick Garnett, "Caterpillar Gets Dug in to $2bn Factory Modernization,'' *Financial Times*, June 6, 1990, p. 14.

Box 4-B—Work Reorganization and Training in U.S. Industry: Two Examples-Continued

Over 3 years in the mid-1980s, CAT lost more than $1 billion. With the return of the dollar to lower levels, the company's income statement improved. Nonetheless, the huge losses were traumatic. CAT has substantially altered its business practices, seeking to reduce exchange rate risks by moving production overseas and purchasing more components abroad. In departing from its past practice of making most of its own parts and components, CAT has sought to shift risks to suppliers. Today, the company continues to operate 17 plants in the United States, but it produces components internally only when it has a substantial cost advantage or wishes to preserve core technological capabilities. Worldwide, Caterpillar now has only 60,000 employees (two-thirds in the United States), compared with 100,000 at the beginning of the 1980s.

To bring down overall production costs, CAT is investing more than $2 billion in its own manufacturing operations. Much remains to be done, but the company has moved toward a JIT system, and reorganized plants around machining and assembly cells fitted with state-of-the-art flexible production equipment. Inventories have been reduced substantially. Although 60 job classifications remain, the number had earlier been more than four times greater. Work groups have been given responsibility for quality, productivity improvements, and meeting JIT delivery schedules. As an example of the results, transmission assembly at CAT's Peoria, Illinois, plant now takes a few days rather than 3 months.

Given a lengthy history of labor discord, the long-term success of the new practices remains to be seen. Less supervision, flatter organizational structures, and ever-sticter demands for higher quality and lower costs require new skills throughout the workforce. CAT's training has traditionally targeted skilled workers and supervisory personnel, but this has begun to change: the company has introduced new programs to help unskilled and semiskilled workers cope with the group-oriented approach to production, which has far less formal structure than found in the company's old plants.

CAT has also begun helping its U.S. suppliers with training, providing them at cost with courses in SPC, blueprint reading, and geometric dimensioning and tolerancing. The company would like to avoid in-coming quality inspections, relying instead on annual certification of vendors, but many suppliers have been unable to meet the new quality targets.

Recently, CAT has become concerned that it may not be able to find enough machinists and other skilled workers in the years ahead. while the firm has revived its apprenticeship program, halted in 1980s as losses mounted, qualified candidates have been scarce.

related group of ''soft' technologies-continuous improvement *(kaizen)* and employee involvement programs, SPC and JIT-to help employees feel comfortable in their new roles. SPC and JIT, for example, frequently function on two levels: as well-defined technical methods, and also as tools for impressing on workers their roles and responsibilities in the redesigned production system. For engineers and managers, SPC functions as a rigorous, quantitative method for monitoring and controlling production. Shopfloor workers may be asked to help-by recording SPC data, trying to analyze it, applying the results where possible-but the primary purpose is motivational, aimed at self-discipline.[12] SPC thus becomes a tool for workers to understand what they are doing and find ways of doing it better. Indeed, SPC in an American firm may not differ much from *kaizen in* a Japanese firm. Box 4-C discusses in more detail these methods for helping organize and manage complex production systems.

The organizational technologies outlined in box 4-C serve as preliminaries to automation, helping companies avoid mechanizing wasteful or ineffi-

[12] This is true not only in the United States, but in Japan, where:

> Groups begin by learning a number of statistical procedures which the foreman has been taught in special courses-tree diagrams, Pareto curves, how to use, if not actually how to do regressions. This is partly for real; these are indeed the techniques which-depending on the nature of the work-place—may be used to identify problems for the group to tackle. Partly, also, they are symbolic-ways of absorbing and expressing a scientific attitude to work; an initiation into a confraternity, a little like the Boy Scout learning his knots.

"Employee Training in Japan,'' report prepared for OTA under contract No.L3-4335 by David Cairncross and Ronald Dore, March 1990, p. 15,

For an extensive comparative study of quality circles and their diffusion, see Robert E. Cole, *Strategies for Learning: Small-Group Activities in American, Japanese, and Swedish Industry* (Berkeley, CA: University of California Press, 1989). On current quality control procedures in U.S. industry, particularly for semiconductors and optical fibers, see "U.S. Investment Strategies for Quality Assurance," Planning Report 90-1, Quick, Finan & Associates for the National Institute of Standards and Technology, April 1990.

cient processes. Once a firm understands its processes and the needs that a reorganized production system must satisfy, it is in a far better position to specify new equipment (recall the Motorola example, box 4-B). In this light, computer-integrated manufacturing (CIM) is evolutionary, not revolutionary.

These stages of refinement and streamlining need not require extensive training in task-specific skills. They do require attention to problem-solving, singly or in groups, and to skill breadth. With JIT or JIT-like systems, there is no time to wait for a supervisor to assess a problem (defective parts, a machine breakdown) and a specialist to fix it. Workers should be in a position to diagnose and solve most such problems themselves. Maintenance training, for example, then serves multiple ends, helping employees understand how equipment operates, and thus how it may fail, as well as enabling the company to reduce its maintenance staff.

How much training is needed when work is reorganized? What makes for good training in support of continuous improvement or employee involvement? These questions have no general answers. But it does seem clear that techniques like those summarized in box 4-C are more likely to prove effective when part of a company-wide reorganization, one that the workforce will accept and believe in. Typically, this means linking reorganization in convincing fashion to the company's competitiveness-hence job security for shopfloor workers. If employees sense a quick-fix effort, or think they will be blamed for future problems, reorganization more than likely will fail.

Supervisors

The supervisor's role in a reorganized factory differs fundamentally from that of the line foreman. There is less need for such traditional supervisory tasks as motivating and disciplining workers, or monitoring performance. When supervisors oversee a number of work groups, becoming coordinators and facilitators, it is more as if the supervisor works *for the* group rather than ***over*** it. For example, the supervisor may become the liaison with the personnel department. Ideally, persuasion replaces authority, with teaching and training added to the supervisor's role. Supervisors also need better diagnostic skills, and, if they work with engineers, some familiarity with technical issues.

Some companies have found that fewer than half their supervisors can adjust, even after training in human relations, participatory management, and organizational technologies like SPC or JIT. Supervisors who cannot make the transition have sometimes found themselves out of work. Other companies have tried to train redundant supervisors for technical support jobs, where interpersonal skills are less important. But these jobs have grown considerably more demanding with the spread of computer-based equipment, and few supervisors, especially those promoted from the factory floor, have an ideal background for filling them. Indeed, the simpler support jobs, like quality control, tend to disappear with reorganization, while others may now call for a college degree (using sophisticated computer models for planning and scheduling-e. g., computer-aided process planning, or CAPP—see app. 4-A).

Engineers

Reorganization, finally, alters the relationship between shopfloor workers and engineering staff. Both product engineers and manufacturing specialists may be expected to act on suggestions and ideas from production workers, join in quality circle and *kaizen* meetings, and otherwise treat shopfloor employees more or less as equals. Many companies have found this to be a painful experience for their engineers, who tend to view themselves as fountains of expertise and the workforce as receptacles.

In the scientific management ideal, there was one best or optimum way to organize production, that way known to the initiates. To the extent that this view still shapes the attitudes of American engineers, they will continue to have trouble working effectively with shopfloor employees. When it comes to process design, engineers often concentrate on the hardware-machinery and equipment—treating the workers as adjuncts, there to do whatever is too complex or expensive to automate. In the extreme, engineers may view automation as a way to get people out of the system because they are sloppy, unpredictable, inefficient-the source of errors. A recent survey finds manufacturing engineers poorly prepared for CIM because interested only in the technology, not in how people can use it.[13]

[13] Detlef K. Koska, "Technology's Impact on the Manufacturing Engineer in the Year 2000," paper presented at Autofact '89 Conference & Exposition, Detroit, MI, Oct. 30-Nov. 2, 1989. The survey was conducted by the A.T. Kearney consulting firm.

Box 4-C-Organizational Technologies

Statistical Process Control

The goal of SPC is to reduce variance in the production process, resulting in more consistent output with fewer and less serious defects, minimum scrap and rework.[1] American firms developed the fundamentals of SPC during the 1920s and 1930s, but the methods have been much more visible since their reimport from Japan, beginning in the 1970s.

By measuring process parameters (e.g., the moisture content of cookies as they enter a baking oven), and examining trends over time, SPC defines the limits past which product attributes begin to deteriorate (e.g., the cookies leave the oven too hard or too soft). Once these limits have been determined, the process can be monitored to keep the critical parameters in the proper range. Seemingly simple, SPC can become quite complicated when dozens of variables are involved, or the process goes out of control and the causes cannot be located.

Many if not most such problems are matters for the engineering staff. Companies train shopfloor workers in SPC methods in large part to impress on them the need for continuous and disciplined attention to their work. Rarely do they expect employees to actually learn anything about statistics beyond a few simple terms like averages and ranges. The intent is to socialize them, integrate them into the production system, and create a self-managing work environment. Still, basic skills are necessary if workers are to enter data and read the control charts that tell them whether or not they are doing a good job.

The example of Plumley Companies, an auto parts supplier in Tennessee, illustrates the impacts of SPC and the training required. During the early 1980s, Plumley was shipping parts with defect rates of 1 in 300; the company had lost its oldest and one of its best customers-Buick. When Plumley tried to implement SPC in conjunction with the installation of new manufacturing equipment, it discovered that nearly half of its 500-person workforce had not completed high school; many employees, including supervisors, were unable to read. The company embarked on an employee education program. With its investments in new equipment, plus SPC, Plumley was eventually able to reduce its reject rate to 1 in 10,000. The firm has won back business from Buick, and gained such demanding new customers as Nissan.

In another example, at a cookie factory, introduction of SPC proved troublesome, but not because of basic skills problems.[2] Managers neither explained the goals of the program adequately, nor provided appropriate training. Bakers, mixers, dough rollers, and machine captains focused on maintaining particular target values for moisture content, line speed, and temperature in each of eight oven zones, without regard for the process as a whole. This missed the point: actions at each stage affected those downstream; turning out cookies with the desired weight, shape, color, and consistency required attention to ranges and trends, rather than specific values. Most parameters must in fact be slightly “off-target:” “tithe dough is too moist, oven temperatures must be a little higher, and perhaps the line speed a bit slower, else the cookies will be too soft. It was only when management attempted to improve the situation through a course in problem solving skills that they realized workers not only misunderstood the purpose of SPC, but resented the way it had been implemented (some, for instance, felt they were simply being asked to do needless paperwork).

Just-In-Time

The central idea behind JIT production (sometimes known, especially in Toyota’s version, as ***kanban) is*** simple: materials, components, and subassemblies should be delivered (to the factory, assembly line, workstation) only as needed. Because JIT minimizes work-in-process inventory and buffers of parts between production stages, it is an essential element in the lean production systems for automobile assembly described earlier in the chapter.

JIT saves money directly through lower inventory levels and reductions in factory floor area (since less storage space is needed). With on-line inspection, bad parts and other production problems surface immediately, rather than days or weeks after the fact. While any disruption serious enough to interrupt the flow of parts can shut down production, this seeming disadvantage lies, in fact, at the heart of the JIT approach: the goal is ***to prevent*** disruptions; this is achieved by making them intolerable. As with SPC, the objective is to keep the process always under control and running smoothly. The costs of disruptions become so high in a JIT system that all workers understand the need to avoid them.

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[1] In a typical example, a manufacturer of nylon stockings reduced defects by more than 80 percent over 7 months through SPC, with no increase in production cost. W. Edwards Deming, *Out of the Crisis* (Cambridge, MA: MIT Press, 1986), pp. 380-387.

[2] ‘‘Training Factory Workers: Three Case Studies,’’ report prepared for for OTA under contract No. N3-2670 by Larry Hirshhorn, Wharton Center for Applied Research, October 1989.

Because a full-blown JIT system marks such a big change in the production process, introduction typically calls for considerable training. For example, workers may need multiple skills so they they can help one another out when necessary. JIT also requires more sophistication on the part of purchasing departments, which, as noted in box 4-A, must select suppliers on the basis of reliable delivery and consistent quality so that inspections of incoming parts can be minimized (and because a batch of bad parts can shut down the plant).

Rather than simply a matter of minimizing inventories, JIT methods actually comprise a broad set of guidelines for designing and coordinating factory production. Understood in this fashion, JIT becomes another way of continually examining each and every piece of the manufacturing process, in all possible lights, looking for potential problems and potential sources of improvement. Toyota's ***kanban*** system, for instance, evolved through a quarter of a century of experience-based learning. When the automaker decided to automate this informal system (named ***kanban*** after the tags used for scheduling), Toyota engineers realized they would first have to spend 2 or 3 years figuring out the logic embodied in the actions of the people running around the plant with their ***kanban*** tags.

Continuous Improvement

Kaizen, or continuous improvement programs, even more than SPC or JIT, should be seen as "philosophy"-a way of keeping workers focused on the need for cost reduction, quality improvement, reduction of waste and scrap. Group problem-solving sessions (e.g., quality circles) and employee suggestion programs have been among the most popular methods for fine-tuning production operations. Workers may meet with supervisors, production planners, or members of the engineering staff to seek and solve problems and make suggestions for improvement (better hand tools, reductions in set-up time).

At the NUMMI plant, for example, small groups of production workers meet periodically to seek ways of modifying assembly tasks or eliminating wasted motion. Improvements may be as simple as rearranging a work station to allow easier access to parts, or as complex as persuading engineers to alter component designs for ease of production. Work groups at NUMMI also help plan training, which has ranged from task-specific skills to human relations and problem-solving. Experience at many companies shows that ***kaizen-like*** programs prove most successful when they include training in both technical skills and group dynamics.

RESTRUCTURING FOR COMPETITIVENESS

This section examines restructuring more broadly, including human resource practices in service industries. While the sources of competitive pressure differ, competition in the services centers on costs and prices, quality and flexibility, just as in manufacturing. Retail banks, for example, advertise low-cost checking accounts, organize production to minimize bookkeeping errors, and invest in automatic tellers to provide round-the-clock service (and cut labor costs). Banks now ask ''customer service representatives to engage in active selling, using computer simulations to demonstrate the virtues of, say, an individual retirement account.[14] As this example suggests, service fins, like manufacturing companies, have begun to manage, train, and motivate their employees in ways that would have been quite foreign 15 or 20 years ago.

From Work Redesign to Organizational Restructuring

At Motorola (box 4-B), managers believe that the days of long production runs of standardized microprocessor chips are pretty much over. They see more customization, requiring a production system that can respond to constantly shifting market demands without cost or quality penalties. In this light, the reorganization of Motorola's Austin plant simply marks the first step in adjusting to the competitive realities of the 1990s. Subsequent steps maybe more difficult. The first phase was limited to the factory floor. Later phases will extend beyond the factory, affecting engineering, marketing, and finance. Bureaucratic obstacles seem inevitable. In this, the future for Motorola resembles that for most of American industry.

New organizational forms emerge gradually, taking on different shapes in different industries and different parts of the world. While the picture

[14] U.S. Congress, Office of Technology Assessment, *International* Competition *in Services*, OTA-ITE-328 (Washington, DC: U.S. Government Printing Office, July 1987), pp. 288-291.

remains cloudy, at the most general level the overall shift can be described as one from ''Fordist" mass production to more flexible organizational structures.[15] There is no need to accept the theorizing that goes with so many of the discussions of both Fordism and flexible specialization to sketch out the implications for training.

Table 4-3 (a slightly abbreviated version of which appeared in ch. 1 as table l-l) traces the shift by contrasting two ideal types: an older model characteristic of U.S. mass production industries in the 1950s and 1960s, and anew model that encompasses many of the changes described in this chapter. Old and new approaches to training appear at the bottom of the table. The new model has been termed flexible decentralization to underline two primary points: 1) investments in flexible automation make shorter production runs possible with little sacrifice in efficiency; and 2) decisionmaking authority is being transferred downward and outward, to semiautonomous divisions and to the factory floor.

Labor-Management Relations

Organized labor has been ambivalent or opposed to several of the changes summarized in table 4-3 (e.g., reductions in job classifications, outsourcing). In some cases, their suspicions have good cause: not a few companies have implemented aspects of the new model, or closed old plants and built new ones in States where organized labor is weak, as part of antiunion strategies. Given continued opposition not only from some union members, but from managers who would prefer not to yield authority to line workers, attempts to reorganize existing plants along the lines outlined in table 4-3, particularly plants with strong unions and a history of labor-management discord, have sometimes proved impossible.

Although many companies seek to avoid unions when restructuring-a number of Japanese transplants have located in rural areas where labor unions have little support-in other cases competitive pressures have spurred cooperation between unions and management. Organized labor has been generally supportive of one of the key elements in table 4-3—transfer of authority downward to the shop floor. At NUMMI, for example, management agreed to hire a majority of workers from among the laid-off employees of GM's old Fremont plant-known for troubled labor relations—while the United Auto Workers (UAW) agreed to accept flexible work rules and only four job classifications. About 240 hourly workers spent 3 weeks at Toyota's facilities in Japan for classroom and on-the-job training prior to plant start-up. These workers then became trainers for the rest of the 2,000-person workforce. NUMMI has maintained high quality standards, while productivity exceeds the GM average by 40 percent.

At GM's own factories, joint labor-management training and quality programs have also had positive impacts. In the company's Hamtramck plant, all assembly is performed by work groups, a Joint Activities Committee meets weekly to evaluate quality and productivity, and employees regularly attend the UAW-GM off-site Paid Educational Leave program.[16] In other examples, a group organized through the UAW-GM Human Resources Center found ways to cut costs of body sealer at the Lansing (Michigan) Body Plant from $8 to $3 per car, while joint committees at stamping plants have managed to dramatically reduce die change times. As discussed in chapter 8, the UAW has negotiated joint training funds with the three major U.S.-owned automakers. These funds are used to promote teamwork as well as provide technical training.

Genuine Change or Cosmetic?

Companies that take a piecemeal approach to reorganization risk failure, particularly those that pick and choose Japanese production practices according to whether managers feel comfortable with them. It is entirely possible that the new

[15]Michael J. Piore and Charles F. Sabel, The Second *Industrial Divide (New* York: Basic Books, 1984); Charles F. Sabel, "Flexible Specialization and the Re-emergence of Regional Economies, ' *Reversing Industrial Decline? Industrial Structure and Policy in Britain and Her Competitors,* Paul Hirst and Jonathan Zeitlin (eds.) (Oxford, UK: Berg, 1989), pp. 17-70; Richard Florida and Martin Kenney, "HighTechnology Restructuring in the USA and Japan," *Environment and Planning A,* vol. 22 (February 1990), pp. 233-252; Paul Milgrom and Jobn Roberts, "The Economics of Modern Manufacturing: Technology, Strategy, and Organization,'' *American Economic Review,* vol. 80 (June 1990), pp. 511-528. Also see *International Competition in Services,* op. cit., footnote 14, pp. 253-287.

[16]Joseph M. Callahan, ''Solidarity in Poletown!'' *Automotive Industries,* June 1989, p. 71. Also see ''UAW-GM Joint Activities at the Plant Level,'' Work in America Institute, Inc., Apr. 19, 1989.

Unions in chemicals, steel, and the airlines, among others, have agreed to flexible job assignments, including material handling, repair, and housekeeping tasks. Harry C. Katz and Jeffrey H. Keefe, ''Industrial Restructuring and Human Resource Preparedness in Unionized Settings," Peter B. Doeringer et al., (eds.), *Turbulence in the American Workplace (New* York, NY: Oxford University Press, forthcoming).

Table 4-3—Changing Organizational Patterns in U.S. Industry

Old model Mass production, 1950s and 1960s	New model Flexible decentralization, 1980s and beyond
Overall strategy	
• Low cost through vertical integration, mass production, scale economies, long production runs. • Centralized corporate planning; rigid managerial hierarchies. • International sales primarily through exporting and direct investment.	• Low cost with no sacrifice of quality, coupled with substantial flexibility, through partial vertical disintegration, greater reliance on purchased components and services. • Decentralization of decisionmaking; flatter hierarchies. • Multi-mode international operations, including minority joint ventures and nonequity strategic alliances.
Product design and development	
• Internal and hierarchical; in the extreme, a linear pipeline from central corporate research laboratory to development to manufacturing engineering. • Breakthrough innovation the ideal goal.	• Decentralized, with carefully managed division of responsibility among R&D and engineering groups; simultaneous product and process development where possible; greater reliance on suppliers and contract engineering firms. • Incremental innovation and continuous improvement valued.
Production	
• Fixed or hard automation. • Cost control focuses on direct labor. • Outside purchases based on arm's-length, price-based competition; many suppliers. • Off-line or end-of-line quality control. • Fragmentation of individual tasks, each specified in detail; many job classifications. • Shopfloor authority vested in first-line supervisors; sharp separation between labor and management.	• Flexible automation. • With direct costs low, reductions of indirect cost become critical. • Outside purchasing based on price, quality, delivery, technology; fewer suppliers. • Real-time, on-line quality control. • Selective use of work groups; multiskilling, job rotation; few job classifications. • Delegation, within limits, of shopfloor responsibility and authority to individuals and groups; blurring of boundaries between labor and management encouraged.
Hiring and human relations practices	
• Workforce mostly full-time, semi-skilled. • Minimal qualifications acceptable. • Layoffs and turnover a primary source of flexibility; workers, in the extreme, viewed as a variable cost.	• Smaller core of full-time employees, supplemented with contingent (part-time, temporary, and contract) workers, who can be easily brought in or let go, as a major source of flexibility. • Careful screening of prospective employees for basic and social skills, and trainability. • Core workforce viewed as an investment; management attention to quality-of-working life as a means of reducing turnover.
Job ladders	
• Internal labor market; advancement through the ranks via seniority and informal on-the-job training.	• Limited internal labor market; entry or advancement may depend on credentials earned outside the workplace.
Governing metaphors	
• Supervisors as policemen, organization as army.	• Supervisors as coaches or trainers, organization as athletic team. (The Japanese metaphor: organization as family.)
Training	
• Minimal for production workers, except for informal on-the-job training. • Specialized training (including apprenticeships) for grey-collar craft and technical workers.	• Short training sessions as needed for core workforce, sometimes motivational, sometimes intended to improve quality control practices or smooth the way for new technology. • Broader skills sought for both blue- and grey-collar workers.

SOURCE: Office of Technology Assessment, 1990.

approaches work because the elements are mutually interdependent. With only some of them in place, the system may perform poorly. Or improvement may be temporary, with the organization later sliding back into its old ways—particularly if higher management does not buy into the entire agenda, but treats it as another way of manipulating employees.

A 7-year business expansion has made it relatively easy for American industry to invest in training and experiment with innovations like those outlined in tables 4-2 and 4-3. The test will come in the inevitable downturn. Some companies in some industries (including, for example, IBM, Hewlett-Packard, Motorola, Pacific Telesis, and a number of large banks) have had long-standing policies of adjusting employment levels through attrition, retraining and redeploying their existing workforce when product or process technologies change, rather than laying off one group while hiring another with needed skills.[17] Facing potential layoffs in its electric motor and transformer plant in Fort Wayne, Indiana, General Electric moved some of its growing production of aircraft engine controls to Fort Wayne, finding it less expensive to retrain hundreds of employees with 20-plus years of seniority than to lay them off and train new people.[18]

Still, overcapacity or recession will from time to time force large cutbacks in the output of some U.S. industries. How will employers respond? A few companies have begun to experiment with concentrated training on company time during periods of slack demand, hoping to upgrade worker skills for the long-term good of the organization. Such policies remain the exception, with many more American firms still subscribing to start-stop practices in training. One point seems plain: firms that seek to adopt Japanese production methods in a full-blown way will not be able to close entire plants for weeks or months.

Sectoral Comparisons

Table 4-3, while cast in terms of manufacturing, could just as easily incorporate terms appropriate for service fins. Table 4-4 givess summary descriptions of the changes underway in four U.S. sectors—two in services (banking and retailing), and two in manufacturing (textiles and automobiles). These help fill in the general picture of restructuring, while illustrating differences among industries. Textile manufacturers, for example, appear the least sophisticated by far in their approach to training.

In both banking and retailing, the forces driving change have been domestic more than international: deregulation in the case of financial services; greater consumer buying power, shifting tastes, and migration to the suburbs in the case of retailing. Financial service firms and retailers have adopted aggressive training and human resource strategies, although, as the table indicates, necessarily quite different from those of manufacturing firms.

Automobile manufacturers pay wages well above the average, and offer attractive fringe benefits (about the same in union and nonunion plants); they have had little trouble finding people with adequate basic skills who can be trained to work effectively in their production systems.[19] In contrast, most low-level jobs in banking and retailing pay far less, yet employers want personable, competent workers-able to deal with the public and convey the desired image.

Not only can few service firms pick and choose their workers, many must live with annual turnover rates of 50 percent or more. As a result, training

17 "Layoffs Called Wrong Approach to Saving Money During Hard Times," *Daily Labor Report,* Sept. 22, 1986. On the other hand, companies including R.J. Reynolds, Eastman Kodak, Bank of America, and Chase Manhattan have abandoned earlier no-layoff policies. John Hoerr and Wendy Zellner, "A Japanese Import That's Not Selling," *Business Week,* Feb. 26, 1990, p. 86. Even IBM has used early retirement incentives to cut its labor force in recent years.

18 Jerome M. Rosow and Robert Zager, *Training: The Competitive Edge (San* Francisco, CA: Jossey-Bass, 1988), PP. 209-212.

One analysis, based on data from several companies, found retraining 100 redundant employees and keeping them on the payroll (doing maintenance and security work) for 6 months to be less expensive than laying them off and then rehiring them when demand picked up. Roxane Dean and Daniel W. Prior, "Your Company Could Benefit from a No-Layoff Policy," *Training and Development Journal,* August 1986, p. 40. Part of the reason was the expectation that some of the laid-off workers would find new jobs, so that the company would have to fully train 25 new people as replacements. Other factors making the layoff alternative more expensive included greater Unemployment Insurance charges, separation payments, administrative costs of both hiring and firing, and lost production due to lower morale among those employees who were retained.

19 In the late 1980s, Diamond-Star Motors, the Mitsubishi-Chrysler joint venture in Bloomington-Normal, IL, hired a workforce averaging nearly 14 years of schooling; more than 50,000 people applied for fewer than 3,000 jobs. Mazda's Flat Rock, MI, plant, which employs 3,100 people, received nearly 100,OOO applications. Richard Child Hill, Michael Indergaard, and Kuniko Fujita, "Flat Rock, Home of Mazda: The Social Impact of a Japanese Company on an American Community," *The Auto Industry Ahead: Who's Driving?,* Peter J. Arnesen (cd) (Ann Arbor, MI: University of Michigan, Center for Japanese Studies, 1989), pp. 69-131. The Mazda plant began production in late 1987; Diamond-Star's first cars left the factory in 1988.

Table 4-4-Restructuring in Four U.S. Industries

Textiles	Automobiles [a]	Banking	Retailing
Response by U.S. firms to competitive pressures, domestic as well as international			
• Product variety within narrower market segments • New investment in automated production equipment	• Renewed emphasis on larger family cars; introduction of small trucks, vans, and utility vehicles • Strategic alliances with Japanese and Korean automakers for small car design and production • Investments in automated production equipment; closing of high-cost plants	• Aggressive movement into offshore markets, and in some oases into foreign commercial banking • New financial instruments for both retail and corporate customers • Heavy use of information technologies, often proprietary (e.g., cash management services)	• Diversification, expansion into specialized stores and market niches (fast foods, luxury goods), and new regional and local markets; smaller stores • Heavy use of information technologies
Restructuring and reorganization			
• Tighter links with suppliers and customers • "Quick response" production systems, with more attention to fashion trends	• New plants somewhat smaller • Closer working relationships with smaller groups of suppliers • Limited vertical disintegration, with selected engineering tasks farmed out to suppliers	• Functional organizations with front and back office collapsed • Greater stress on safes, marketing, customer service	• Decentralization of decisionmaking to store managers • Integrated, computer-based inventory, ordering, and point-of-safe systems
Labor market supply conditions (Many of the shortages noted reflect prevailing wage levels)			
• Shortages of workers with adequate basic skills, high school education • Shortages of skilled technical workers and entry-level supervisors	• Continuing reductions in both white-collar and blue-collar workforces • Shortages emerging in some skilled trades due to cutbacks in apprentice training during the recession years of the early 1980s	• Shortages of workers with adequate basic and social skills for customer service jobs in retail branches	• Shortages of workers with adequate basic and social skills, especiafly in some urban areas, for jobs requiring customer contact • No consistent source for managerial tracks
Recruiting and human resource strategies			
• At lower levels, take all comers • Efforts beginning to work with community colleges	• High prevailing wage levels help automakers recruit young workers with high school and beyond	• Hire more female, temporary, and part-time workers • External hiring for management ranks (e.g., directly from college), rather than promotion from within • Eliminate low-skilled jobs through automation, self-service	• Seek new sources of temporary and part-time workers-e.g., women, students and retirees • Internal promotion to management levels, but increasing insistence on college as a prerequisite • Elimination of low-skilled jobs through automation, self-service (e.g., in gasoline stations)
Skill changes and job design			
• More operator responsibility for quality, monitoring of equipment performance, and routine maintenance; basic skills needed • Repair work more complex	• Selective use of multiskilled work groups • Operator responsibility for quality, some routine maintenance, simple troubleshooting	• Lower level employees assigned broader range of tasks (e.g., selling) • Computer literacy may be needed	• Safes clerks responsible for credit card verification, data entry • Some computer literacy may be desirable
Training strategies			
• Basic skills programs • Technical training through community colleges and equipment vendors	• More cross-training; emphasis on quality control practices (e.g., SPC) • Training programs used to build employee allegiance to corporate goals • Basic skills and adult education courses through joint union-management training programs	• Basic skills for entry-level workers • Training in proprietary information systems • Intensive training for managerial candidates	• Brief but intensive training for entry-level workers • Extensive training for managers as they progress upward

[a]Vehicle manufacturers, including Japanese-owned transplants, but not suppliers.

SOURCE: Based in part on "Training and Competitiveness in U.S. Manufacturing and Services: Training Needs and Practices of Lead Firms in Textiles, Banking, Retailing, and Business Services," report prepared for OTA under contract No L3-3560 by Lauren Benton, Thomas Bailey, Thierry Noyelle, and Thomas M. Stanback, Jr., Columbia University, February 1990, Table 01.

programs are brief but intensive, stressing basic skills, firm-specific workplace technologies (e.g., point-of-sale terminals), and customer relations. Although both banks and retail outlets have traditionally employed many women, longer business hours (themselves in part a consequence of the greater number of working women) have led to an even greater focus on women as part-time workers. Firms in these sectors, finally, as in a number of other services, place demands on supervisors and managers quite different from those in manufacturing organizations. As noted in the table, large banks and retailers have developed formal procedures for selecting managerial candidates, and training them at successive levels of the management track.

Changing Practices in Employment and Training

Supply and Demand

Generally companies retrain existing employees when they redesign their production processes. Moreover, in high-turnover industries, like many of the services, half the workforce is new each year, so that training must be built into ongoing operations. As illustrated by the examples in box 4-B and elsewhere in the chapter, training an existing workforce is not so easy as it might seem. Many companies have found that existing skill levels have simply not been good enough. Even so, few executives in major corporations see poor basic skills as a barrier that cannot be overcome. What frustrates industry is the double burden of providing remedial education to improve the skills of high school graduates who cannot read or do simple arithmetic (and who may show no interest in learning), before being able to train in job-specific technical skills. To avoid this, companies in a position to be selective build more filters into the screening process before they hire.

No longer is a high school diploma accepted as a meaningful credential. Some personnel departments have also adopted tests intended to measure how well people perform in a small group setting, while applicants may have to be approved by the production group they will join. As such trends imply, in the longer term, hiring and training practices, particularly in manufacturing, will probably change quite substantially. Wage levels may have to rise, if manufacturing firms-many of which pay much less than in such traditionally unionized sectors as autos or steel—are to attract workers with the needed capabilities. Many young people who once might have taken jobs in manufacturing now go on to a junior or community college; fewer seem interested in pursuing a factory-bound career. It has become difficult for many U.S. firms to find, not only production workers with adequate skills, but technicians and engineers willing to work on the shop floor. Still, managers of large companies generally see the most serious problems, not in their own organizations, but in their suppliers-particularly small firms that not only pay low wages but do little or no training.

Contingent Workers

As noted in tables 4-3 and 4-4, American companies have begun relying more heavily on contingent workers—those without formal or long-lasting ties to an employer. During the 1980s, temporary and part-time employment grew at roughly twice the rate of permanent, full-time employment, and now accounts for about one-quarter of all U.S. jobs.[20] For employers, replacing full-time staff with short-term, project-related, or part-time employees provides a simple way to adjust for variations in demand. Work may be subcontracted to small fins, or to individuals. Subcontractors, in turn, may have people on call so that they can respond quickly. Firms that rely on contingent workers can lay off part of the workforce when times are bad, while avoiding some of the costs (e.g., fringe benefits) of a larger core of permanent employees.

Much as in more primitive economies where casual work is common, contingent workers act as buffers. Employers have been able to push much of the risk associated with business downturns, illness, and other interruptions in people's ability to work onto individuals. (While some contingent workers eventually become eligible for fringe benefits such

[20]Richard Belous, ''Future Labor Force Requirements,'' presentational Congressional Research Service, July 26, 1989. Including illegal immigrants, work in the underground economy (most of which is simply unreported, not illegal or otherwise illicit), the self-employed, and those who work at home would increase the fraction significantly. *See International Competition in Services*, op. cit., footnote 14, chapter 7, from which portions of the discussion below draw.

Twenty percent of the 645 firms in the 1990 Towers Perrin/Hudson Institute survey reported that they have a core/contingenworkforce; another 11 percent are moving in this direction. ''Workforce 2000-Competing in a Seller's Market: Is Corporate American Prepared? A Survey Report on Corporate Responses to Demographic and Labor Force Trends," op. cit., footnote 3, p. 24.

as retirement plans, health insurance, and paid vacations, most do not.) Rarely does a contingent job represent one step on a career ladder; indeed, almost by definition, contingent workers have no access to internal labor markets, and thus little opportunity for on-the-job training.

But, like the "fire-and-hire" approach, reliance on contingent workers may be more expensive for companies than first appearances would suggest. By definition, contingent workers are hard to integrate into group-based production systems. Not only do they lack company-specific training, and commitment to corporate goals, they may not have needed task-specific skills-a particular problem in periods of rapid expansion. When companies design standardized jobs that can be performed by temporaries, whether brought in for 2 days or 2 months, they may be sacrificing efficiency. Over the longer term, companies that rely too heavily on part-time and temporary employees may find that they have substituted flexibility in numbers for the flexibility created by a workforce rich in experience-based skills and know-how.

CONCLUDING REMARKS

New technology in the workplace, new forms of work organization, and the overall shift towards service industries have accelerated the need for training in the U.S. economy. As companies move toward more flexible systems of design, development, and production, they must complement their investments in computer-based technologies with investments in better-trained workers. The needed training goes beyond skills for operating particular pieces of equipment. Restructured organizations cannot function without a workforce that is both well-trained and well-motivated. Increasingly, managements encourage shopfloor employees to view themselves as individually responsible, each in their own small way, for the continued success of the enterprise. Allocating more responsibility and authority to individuals and groups requires attention to both hiring practices and training.

While many plant managers believe that upper-level executives continue to undervalue manufacturing, a growing number of American companies realize that it will take renewed attention to the factory floor to solve their competitive problems. One result: training managers may become members of strategic planning groups-a status unheard of just a few years ago. With more training, workers become more comfortable in learning environments and better able to adapt to new production technologies. Companies that recognize this virtuous circle for what it is have taken a major step toward continued competitive success.

APPENDIX4-A-C0MPUTER-AIDED TECHNOLOGIES IN U.S. MANUFACTURING

Advanced manufacturing technologies come in many varieties. Companies seek lower costs through near-net shape processing (e.g., precision castings in place of machined forgings) and better functional performance through improvements in heat treatment or surface hardening. They specify new materials, including fiber-reinforced composites, which require new processes, and look to automated inspection procedures to locate one-in-a-million defects that would be impossible for human operators to spot.

This appendix first outlines major categories of computer-aided technologies used in manufacting-with no attempt to be comprehensive. The context is one of metalworking rather than the chemical or electronics industries (although many computer-aided technologies can be employed in a surprising variety of production settings). Later sections of the appendix discuss diffusion within American industry and the effects of programmable automation on skills.

Toward Computer-Integrated Manufacturing

Many if not most of the thousands of processes found in U.S. manufacturing share a common attribute: they depend, in one way or another, on computer-based control systems. For many years, the chemical industry has used automated process controls. Once, a control system would have had to be specially designed for a given application. Today, generic components can be programmed via software for abroad range of applications. In steelmaking, optical and electronic sensors monitor the chemistry and temperature of molten metal, feeding information to process control computers. In machining, numerical controls (NC) that once required off-line programming are giving way to controllers that can be used much like a PC.

The great advantage of the computer for automation lies in its flexibility: computers can be reprogrammed, not only for new applications, but to make minor modifications in existing processes. For many years, computers were too expensive to find many applications on the factory floor, but with the development of, first, minicomputers, then the microprocessor and the PC, hardware cost is no longer the chief obstacle. Rather, the cost barriers lie mostly in software, and in integration. Software programs must not only be written for each new application, they must be debugged and maintained. Integration-locating and assembling equipment that can be linked together, devising software that effectively coordinates equipment from different vendors-often proves much more difficult than initially expected.

Computer-integrated manufacturing (CIM) thus remains an objective more than a reality. Yet many firms have moved quite a long ways down this road over the past two decades. And if some of the past efforts to implement computer-integrated manufacturing now seem overambitious, that should be no surprise. Technological innovation of any stripe brings with it unanticipated difficulties more frequently than unexpected serendipities. The great difference between adopting computer-based control systems for factory automation and computer-based systems, for, say, aircraft flight control is simply that American companies would normally put their best technical people to work on aircraft flight controls, and give them ample budgets, while leaving manufacturing systems to less competent people with less than ample budgets.

Programmable automation began in the 1950s and 1960s, with NC machining and early computer graphics systems. Gradually, these and other stand-alone applications began to be linked through networks and common databases. While the process of integration remains a long way from completion, CIM will eventually be commonplace. The companies that can most quickly and most effectively make something useful of acronyms such as those below will move ahead in international competition:

- CAD, or computer-aided design. In fact, most CAD systems remain limited to computer graphics, the automation of drafting and preparation of bills of materials. Some can generate NC part programs. Such tasks as maintaining databases of drawings and specifications, and making the changes called for during development-often running into the dozens, if not hundreds, for a single part-have become much more manageable.
- CAM, computer-aided manufacturing. Descendants of NC machining, CAM installations today typically link several machines, along with robots and materials handling equipment, to create an automated machining cell or a flexible manufacturing system (FMS-the difference is simply one of scale). Only a few hundred large FMS systems have thus far been built.

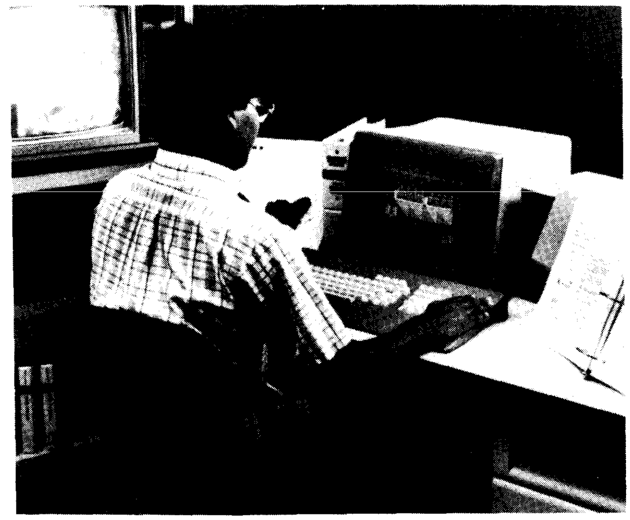


Photo credit: American Association of Community and Junior Colleges

Interactive video training in the use of a computer-aided drafting system.

- CAPP, computer-aided process planning. Many shops now schedule jobs and manage work-in-process inventories with the aid of small computers and commercially available software packages. More American firms make use of CAPP than any other computer-based manufacturing technology.
- CIM, computer-integrated manufacturing. CIM implies combining CAD and CAM, and typically CAPP as well. The primary objective: moving from design to production without an intervening stage of paper drawings and process plans-from CAD to CAM more-or-less automatically. For practical purposes, such systems do not yet exist, except for a few specialized cases such as very large-scale integrated circuits.

As these technologies develop and diffuse, some workplace skills will become obsolete-because taken over by automated equipment-while demand will grow for others, including systems analysis, programmingg, and maintenance of both hardware and software. A big part of the job for analysts, designers, and programmers is to put together CIM systems that are easy for unskilled workers to use. To the extent they are successful, training and retraining for users will be straightforward.

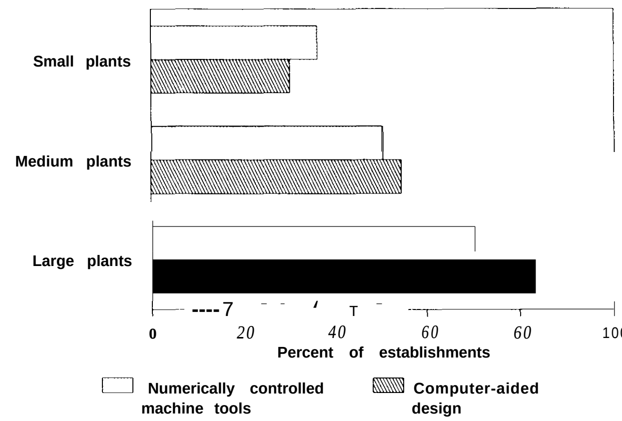
Penetration of Programmable Automation[21]

Surveys indicate that no more than10or11 percent of installed machine tools in the United States have NC capability (about the same as in Japan, although the Japanese machine tool inventory is substantially newer). Over 30 percent of these NC machines are at least 10 years old. Nearly 40 percent of the total consists of simple models that can read instructions but do not incorporate computer controls-technology that has been available for more than 25 years.

None of this should be very surprising. Machine tools have useful lives measured in decades. The stock turns over slowly, with companies retaining older tools as back-ups, even if they rarely use them. Moreover, investment in CIM-related equipment (including CAD, CAPP, programmable controllers, and local-area networks, as well as NC machines) grew at about 15 percent annually during the years 1983-1989-quite a high rate. Two-thirds of U.S. manufacturing establishments have implemented at least one CIM-related technology (and nearly half have at least one NC machine tool). More companies have invested in CAD and CAPP than in NC machinery because the investments are smaller-at the minimum, simply a PC and an off-the-shelf software package. In sum, computer-based manufacturing technologies seem to be diffusing at about the pace that would be expected based on past experience with other technological innovations. Vexing problems in practical application tend to counterbalance the economic driving forces. At the same time, many smaller companies have plainly failed to grasp the logic of programmable automation, and thus have not made investments that would be cost-effective.

Penetration varies with plant size and industry sector, with a relatively few firms, mostly large, accounting for most investments. In 1984, for instance, more than half of all industrial robots could be found in the plants of IBM plus the Big Three U.S. automakers. In 1986, one-quarter of all manufacturing establishments accounted for nearly 85 percent of the CIM-related investment total. According to the Census Bureau survey cited in footnote 21, large establishments make more use of programmable automation than smaller plants (figure 4A-l). Ninety-four percent of manufacturing establishments employing 500 or more people have invested in at least 1 type of computer-assisted technology, versus 67 percent of firms with fewer than 500 employees. Larger plants tend to have more types of programmable automation in place; 80 percent of the large establishments sampled had at least five different advanced technologies, but only 20 percent of small and medium-sized firms.

Figure 4A-l—Penetration of Numerically Controlled Machine Tools and Computer-Aided Design by Plant Size[a]



[a]Small plants have 20-99 employees; medium, 100-499; large, over 500

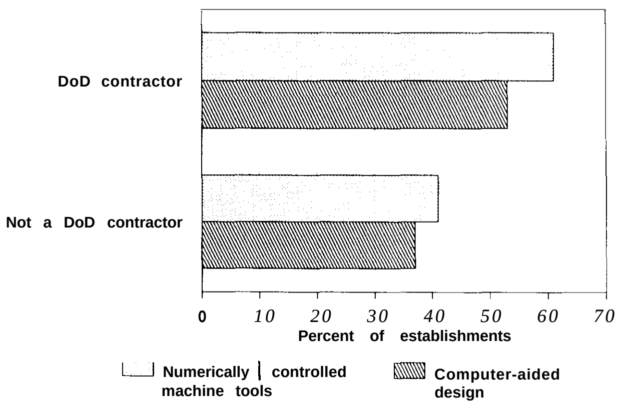
SOURCE: *Current Industrial Reports: Manufacturing Technology, 1988* (Washington, DC: Department of Labor, Bureau of the Census, May 1989), pp. 31,35.

Companies that do most of their business with the Defense Department or other Federal agencies (e.g., the National Aeronautics and Space Administration) make greater use of advanced technologies than those selling primarily to the private sector (figure 4A-2). In the Census survey, 87 percent of plants that viewed government as their primary customer had installed at least one CIM-related technology, compared to 62 percent of plants selling in other markets. Prime contractors and subcontractors show broadly similar patterns of adoption; regardless of their size, firms that make products to military specifications rely more heavily on programmable automation than others.

Most companies surveyed report that improvements in product consistency and quality (more than 80 percent) and reductions in labor costs (78 percent) have motivated their investments. Nonadopters often believe that available technologies are not applicable to their operations, or are not cost effective. Two-thirds of managers in establishments without computer-based equipment reported that their production mix (number of different part designs, average lot sizes) did not just@ automation. In

[21]This section summarizes the results of several recent surveys of the adoption by J.S. manufacturing f- of computer-assisted technologies. Most of the information comes from Maryellen Kelly and Harvey Brooks, "The State of Computerized Automatiorin U.S. Manufacturing," John F. Kennedy School of Government, Harvard University, October 1988; and *Current Industrial Reports: Manufacturing Technology 1988* (Washington DC: Department of Commerce, Bureau of the Census, May1989), as summarized in "U.S. Manufacturing: Problems and Opportunities in Defense and Commercial Industries," staff paper, Office of Technology Assessment, May 1990. Also see Edith Wiarda, *Frostbelt Automation: The ITI Status Report on Great Lakes Manufacturing (Ann* Arbor, MI: Industrial Technology Institute, September 1987). On the situation of smaller firms, see Philip Shapira, *Modernizing Manufacturing: New Policies to Build Industrial Extension Services* (Washington, DC: Economic Policy Institute, 1990).

Figure 4A-2—Penetration of Numerically Controlled Machine Tools and Computer-Aided Design Among Defense and Nondefense Firms



SOURCE: *Current Industrial Reports: Manufacturing Technology, 1988* (Washington, DC: Department of Labor, Bureau of the Census, May 1989), pp. 31,35.

many cases, these perceptions are no doubt accurate, but the survey results also suggest that some managers do not grasp the capabilities of programmable automation and the benefits to be gained.

Both adopters and nonadopters report difficulties in financing purchases. At the same time, some companies have invested in NC equipment, not because it fits their strategic plan or makes economic sense, but simply on an ad hoc basis when replacing worn-out conventional tools. One-quarter of companies that have purchased automated equipment made no further investments during the past 5 years. The surveys, finally, suggest a widening gap between adopters and nonadopters, with most of the new investments over the next few years likely to be made by companies that already have experience with programmable automation. Fewer than 1 in 10 of the establishments reporting no such equipment as of 1987 planned to make purchases over the next 3 years.

Impacts on Skills

Automation not only affects job opportunities, it changes skill requirements, sometimes in the direction of deskilling, sometimes upskilling.[22] At the level of the firm, automation often correlates with new hiring rather than layoffs because companies typically invest in new technologies when business is good Overtime, of course, since the intent is to increase productivity, the firm's employment may decline. For the economy as a whole, the effects of automation depend on the relative rates of growth in output and productivity. Both are uncertain, and none of the many predictions made over the past decade has won widespread acceptance.

When it comes to skill requirements-and the long-running debate over deskilling (whether or not automation, by reducing overall skill requirements, forces a growing fraction of workers to function simply as machine tenders)-the patterns are equally complex. When CAD programs ran on mainframe computers, for example, they were used mostly by engineers and computer specialists, who looked to CAD for help with complex geometrical tasks. In an aerospace company, the same people would often use the CAD system and modify the program (sometimes without telling anyone).

Today, high school graduates with relatively little specialized training can use the turnkey CAD systems available from numerous vendors.[23] So far, these systems have had most of their impact through the automation of such labor-intensive tasks as production of finished drawings based on preliminary sketches. In earlier years, these sketches would typically have been passed along from engineers to drafters who worked at a drawing board. Now the drafting function takes place at computer terminals. Not only drawings of mechanical parts and components, but architectural renderings, electrical, piping, and plumbing layouts, and highway routings can be produced in 10 or 20 percent of the time once necessary.

Though good basic skills are required to use these systems, it takes less training to become a capable CAD operator than to become a competent drafter. While CAD opens up new avenues for the design engineer, the drafter's job has been deskilled. Companies that rely primarily on CAD systems commonly hire people with vocational-technical schooling, but no more than, say, a year's manual drafting experience. They feel that those with more experience will be overqualified (and perhaps overpaid), and unable to adapt as well to an automated work environment.

Early generations of NC technology, somewhat similarly, depended on skilled technicians and engineers to keep the equipment running and improve performance (e.g., through efficient programming). The paper tapes that guided the machines had to be prepared using specialized and complex computer languages. The part programmers who prepared these tapes needed some design skills, as well as knowledge of machining prac-

[22] For a recent summary focusing on conceptual issues in this long-running debate, see Paul Attewell, "Skill and Occupational Changes in U.S. Manufacturing," draft prepared for the conference on Technology and the Future of Work, Stanford University, March 28-29, 1990. For sharply contrasting interpretations of data and projections for the future, see Lawrence Mishel and Ruy A. Teixeira, "The Myth of the Coming Labor Shortage: Jobs, Skills, and Incomes of America's Workforce 2000," Economic Policy Institute, Washington, DC, 1990; and John Bishop and Shani Carter, "The Deskilling vs Upskilling Debate: The Role of BLS Projections," draft, July 18, 1990.

[23] *International Competition in Services,* op. tit., footnote 14, p. 274.

tices. They also had to be well versed in programming. Skilled maintenance workers were needed to oversee the balky and unreliable electro-mechanical tape readers. Machine operators, however, became machine monitors. They were deskilled because the equipment was viewed as too complicated to permit them to write programs or intervene in operations; they loaded and unloaded parts, and watched for malfunctions.

Current generations of microprocessor-basedNC equipment feature help screens and prompts, much as found in software packages for word processing. With a week or so of training, most workers can begin using the simpler systems. Because the equipment is straightforward and reliable, semiskilled shopfloor workers can now do a good deal of programming themselves, limited not by their computer skills but by their knowledge of machining (just as word processing software can catch simple entry or spelling errors but not syntactical mistakes). Maintenance requirements have also changed with the shift from tape readers to direct computer control.

The surveys cited earlier in the appendix (footnote 21) indicate that about two-thirds of NC machine operators have at least "some programming" responsibility, with one-half having "major programming' responsibility. In effect, part programming has now been deskilled; operators and machinists can take back some of the responsibility. Machinists who prepare and debug programs find their jobs have been reskilled. Operators who once simply tended automated machines but now take on some part programming find their jobs upskilled. While few companies cite skill deficiencies as a barrier to purchases of CIM equipment, some report lack of skills to be a barrier to implementation, especially when it comes to maintenance.

Many of the mid-level skills will disappear, as NC systems grow still more sophisticated. Today, CAD systems can automatically generate only simple NC programs. As development of integrated CAD/CAM proceeds, more complex programming tasks will be automated. Eventually, the system will do everything except handle the exceptional cases. Because they are exceptional, these will have to be routed to highly skilled workers, perhaps engineers, who can resolve ambiguities and make decisions requiring trade-offs and design compromises.

As both the CAD and NC examples suggest, programmable automation deskills some jobs and upskills others. When, for example, GM's Linden, New Jersey, assembly plant installed robots for welding, painting, and glass sealing, skill requirements for production employees decreased while those for maintenance workers increased Effective application of CAPP requires considerable training, because complex scheduling algorithms replace the rules-of-thumb previously used. Interpreting the results and making effective use of them demands at least as much expertise and judgment as the older procedures—but expertise of a different sort.

Programmable automation shifts the mix from repetitive tasks (loading/unloading, checking dimensions, monitoring) toward set-up and maintenance, as well as preparing and editing programs. Skill shifts, moreover, may be cyclical, as in the case of NC machine operators—whose work was first deskilled through automation, then upskilled as programming became simpler, and in the end will probably be deskilled again, as programming itself is more fully automated. The general pattern appears to be one in which much of the early technology development is done by users. Typically, those users are highly skilled-often engineers. As the technology matures, vendors take over most of the development. The highly skilled work migrates from users to equipment suppliers, with jobs in the user firms generally being either deskilled (CAD operators in place of drafters) or reskilled (NC programming in place of manual machining).

At the same time, looking at the effects of new technologies on a task-by-task basis can be misleading. While any one task-or all the tasks for a given worker—may become easier, the job as a whole may become more difficult because of the mix of tasks or the speed of production. Often, new equipment operates faster. Moreover, the company will seek to keep it running to maximize the payback on its investment. Operator errors and downtime become more costly. (Japanese factories are notorious for the pressure placed on individual employees.) Preventive maintenance and process quality are likely to become more important. Emphasis on quality and avoiding mistakes requires a broad understanding of the production process. With companies pushing for flexibility (shorter production runs, more frequent product change), employees will find themselves engaged in a wider range of activities. These activities will change more frequently, putting a greater premium on alertness and diligence, as well as continuing on-the-job learning.