Chapter 8

The Effects of Technological Change on the Nature and Availability of Jobs

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of technology to replace human labor.[2] At the same time, unless demand and output are rising faster than labor productivity, some jobs will be lost. Yet if U.S. industry does not become more productive, many sectors are likely to lose out to foreign competition and even more jobs will disappear.

Overall demand remains the central factor determining the number of jobs created or displaced. Increased productivity can lower a firm's or an industry's costs, thus enhancing competitiveness, raising consumption, and creating more jobs. Moreover, when labor-saving technology is introduced during a time of general economic growth or is adopted gradually, normal attrition may take care of all or most reductions in the work force without any need for layoffs. For these reasons, increases in labor productivity do not necessarily equate to displacement. In addition, technological advances that create new products and new consumer demand are a powerful force for economic growth and the creation of new jobs.

Labor productivity is only one factor determining U.S. competitiveness. Other elements include: good labor-management relations, well-trained employees, improved design so that products can be made more easily and perform better, and higher quality in terms of meeting design specifications more closely, Labor productivity is important to lower costs and greater competitiveness, but it is one among many contributing elements.

An example of an approach to improved competitiveness that includes higher labor productivity, a better product, and improved labor relations comes from General Electric (GE) plant making household dishwashers in Louisville, Kentucky.[3] The plant underwent a major modernization program in the late 1970s. Aware of advances in Japanese manufacturing, GE rejected an $18-million proposal to make incremental improvements in the plant and instead chose a $38-million program to cut costs, improve quality, and protect the company's competitive position.

While making major changes in the manufacturing process, the program also altered product design and the use of human resources. By 1983, the refurbished plant was in full operation. The newly designed dishwasher is less expensive to manufacture and is of higher quality. The rejection rate in GE tests has dropped, the number of customer service calls has fallen, and the dishwasher was rated highly by an independent consumer organization, While output per employee rose 33 percent, increased demand for the product kept plant employment stable.

In the past, manufacturing procedures at GE were developed after the product designers had completed their work. For the Louisville program, the product and process were designed together by a multidisciplinary team, The product design allowed the use of a highly controlled manufacturing process, including a central computer and microprocessors at several points in the process. The interior of the dishwasher is a one-part plastic tub, produced automatically by a series of high-pressure injection molding machines. Molded-in features reduce the number of parts requiring assembly and allow many assembly tasks to be automated. The tub travels through numerous stages of production via an automated material-handling system. Throughout subassembly, parts are manufactured as needed, so that inventory costs are kept to a minimum.

The program also included a new approach to employee relations. Management discussed with union officials and first-line supervisors the market and business conditions impelling change. Employees were retrained for their new assignments, and information centers were established on the shop floor to keep communication channels open. The production equipment was designed to give workers greater control over their work environment than in

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[2] Historically, the United States has been particularly resourceful with labor-saving devices. See, for example, H.J. Habakkuk, *American and British Technology in the Nineteenth Century; The Search for Labor-Saving inventions* (New York: Cambridge University Press, 1962).

[3] Based on an OTA site visit and on James Stevens, "Forging the Focused Factory," *Appliance,* June 1983, pp. 34-39; Steven C. Wheelwright and Robert H. Hayes, "Competing Through Manufacturing," *Harvard Business Review, vol. 63,* January-February 1985, pp. 99-109; H. Garrett DeYoung, "GE: Dishing Out Efficiency," *High Technology, vol. 5,* May 1985, pp. 32-33.

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traditional assembly line jobs. For example, in final assembly, an overhead conveyor positions the near-complete dishwashers. The person assembling each unit can adjust the swiveling carrier that holds the dishwasher to a comfortable position. Also, the conveyor system is designed so that workers have more than the usual control over the pacing of tasks.

In the GE Louisville plant, it is difficult to isolate the effects of improved labor productivity from other factors that helped to lower unit production costs and improve competitiveness. Automation of the plant, including integration of the product design with new manufacturing equipment and processes, contributed to raising labor productivity. The new approach to labor-management relations and extra training for the work force may also have contributed to higher labor productivity, and probably helped to improve utilization of the new capital equipment as well. The lower rejection rate after in-plant tests helped to hold down costs. The greater reliability in use (as evidenced by fewer service calls) and the design characteristics of the new dishwasher made it appealing to customers. All these factors combined contributed to increase sales, which resulted in no loss of jobs, despite higher labor productivity.

It is also difficult to isolate the effects of technology (in the sense of product design and productive apparatus) in improving labor productivity. In general, technological change rarely occurs in an otherwise unchanging environment. Other factors, such as labor-management relations, may change as well. The moving assembly line, developed by Henry Ford in 1914, is one of the best-known examples of productivity-enhancing technological advance. This innovation was credited with an eightfold improvement in productivity over traditional methods, which brought the cost of an automobile within the reach of a mass market.[4] However, Ford's innovations were not confined to technology alone. He also made significant changes in labor policy, offering an 8-hour workday and doubling wages, to $5 per day. In this historic case, the role of technology cannot be entirely separated from other factors affecting productivity.

Different Measures of Productivity

Another way to illuminate the importance of human factors in raising productivity, lowering costs, improving quality, and maintaining competitiveness is to consider different measures of productivity. The term "productivity" usually denotes output per unit of labor, but it can refer to both labor and capital, as in the following definitions:

- labor productivity: output per labor-hour;
- capital productivity: output per unit of capital (physical assets); and
- multifactor productivity: output per unit of labor and capital, measured in dollars. s

The Bureau of Labor Statistics (BLS) compiles data on productivity as output divided by units of both labor and capital, and analyzes the data by sector for private business, private nonfarm business, and manufacturing." Rising labor productivity combined with rising capital expenditures indicate that technology is being used to make labor more efficient and to limit the wage bill. This is a familiar concept, and generally describes the pattern in U.S. industry since World War II. The less familiar measure of capital productivity indicates how efficient the use of equipment, inventories, buildings, and land is, in terms of raising output. Equipment—the capital asset that embodies new technologies—was the fastest rising capital input from 1948 to 1981, growing 5 percent per year.

As figure 8-1 shows, output per hour for all persons (labor productivity) rose more than twofold from 1948 to 1984. Output per unit of capital assets, on the other hand, did not rise. For over three decades there was "no apparent long-term savings in the amount of capital services required to produce a unit of output."[7] New technology, therefore, has not lessened capital costs in the U.S. economy since World War II; it has served to limit labor expenditures. In other industrialized nations, capital productivity declined since 1955—except for Japan, which experienced a moderate rise.[8]

The reasons why U.S. capital productivity stayed flat for nearly 40 years are not clear, but its failure to grow argues for greater attention to the efficient use of technology. This may come about through widespread adoption of tactics that many successful companies here and abroad already use; for example, closer links between product design and manufacture, less idle time for capital equipment, better training for employees so they can use equipment more effectively, and improved labor relations that give employees a greater say and greater stake in the future of the enterprise.[9] More efficient use of capital equipment can also contribute to lower costs and higher quality. Attention to improving human capital is also likely to raise labor productivity as well as capital productivity.

Both technology and people are vital resources for more efficient economic production. A sur-

[4]William J. Abernathy, *The Productivity Dilemma: Roadblock to Innovation in the Automobile Industry* (Baltimore: John Hopkins University Press, 1978).

[5]Output is estimated in dollars, adjusted for inflation.

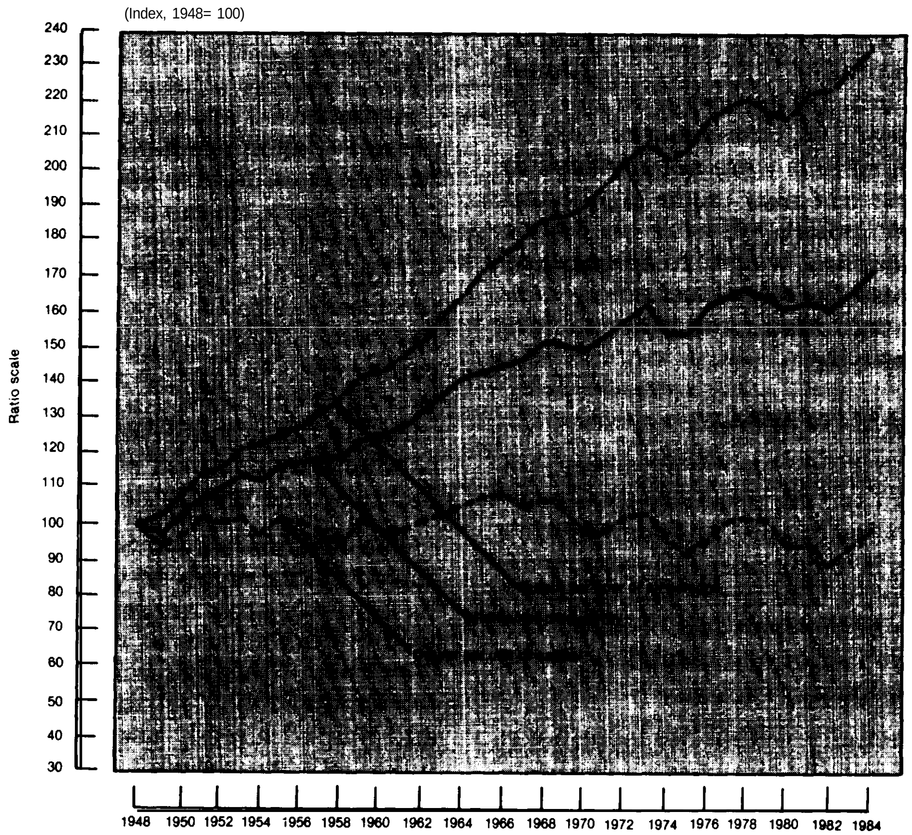
'U.S. Department of Labor, Bureau of Labor Statistics, "Trends in Multifactor Productivity, 1948 -1981,"Bulletin 2178, September 1983. The analysis excludes government enterprises, which accounted for 2 percent of total business output in 1981.

'Ibid., p. 16.

[8]Luc Soete and Christopher Freeman, "New Technologies, Investment and Employment Growth, " *Employment Growth and Structural Change* (Paris, France: Organisation for Economic Co-operation and Development, 1985), p. 67. For a review of Canadian manufacturing, see Uri Zohar, *Canadian Manufacturing: A Study in Productivity and Technological Change, Volume I: Sector Performance* and *Industrial Strategy* (Toronto: James Lorimer & Co., 1982),

'See, for example, Harry Maier, "Innovation, Efficiency, and the Quantitative and Qualitative Demand for Human Resources," *Technological Forecasting and Social Change, vol. 21, 1982,* pp. 15-31; Soete and Freeman, op. cit., pp. 52-82.

Figure 8-1.–Private Business Sector: Output per Hour of All Persons, Output per Unit of Capital, and Multifactor Productivity, 1948-84



SOURCE: U.S. Department of Labor, Bureau of Labor Statistics, "Trends in Multifactor Productivity, 1948-1981," Bulletin 2178 September 1983 p. 22; and *Monthly Labor Review,* vol. 108, No. 11, November 1985, p. 99.

vey of industrial engineers, for example, indicates that effective strategies for increasing overall productivity rely on people as well as machines (table 8-l). Of the organizations surveyed, 69 percent undertook employee involvement programs; the engineers rated 63 percent of these programs successful in raising productivity. Worker training was used less frequently, but was rated 74 percent successful. The engineers found that capital investment for new or automated machinery was 86 percent effective, but the introduction or expansion of robotics was successful less than 50 percent of the time.

Technology, Productivity, and Demand

Technology, productivity, and demand affect each other and also affect employment. Productivity gains, by lowering costs, can stimulate greater demand. Rising demand can offset the employment-shrinking effects of gains in productivity.

In telephone services, for example, technology promoted dramatic increases in labor productivity and also contributed to rapid growth in demand (figure 8-2 and table 8-2). Computerized switching and direct long-distance dialing resulted in falling costs for long-distance service and generally lower rates (in constant dollars) to customers.[10] While employment in

[10] While costs of long-distance calls were falling, Costs of local service rose, reflecting rising input prices and the lack of technological changes comparable to those of toll calls. Until 1982, the AT&T system used some of the revenues from long-distance calls to reduce local service rates (in constant dollars). See U.S. Congress, Congressional Budget Office, ***The Changing Telephone Industry: Access Charges, Universal Service, and Local Rates*** (Washington, DC: U.S. Government Printing Office, 1984).

Table 8-1.—Productivity Improvement Activities Undertaken in the United States, Based on a Survey of Industrial Engineers

New activity	Undertaken activity	Effective
Formal employee involvement in productivity improvement planning and evaluation (quality circles, suggestion programs, etc.)	68.7%	63.1%
Evaluating performance and establishing specific productivity improvement targets	63.3	66.7
Introduction or improvement of inventory control methods	64.4	70.8
Capital investment for new or automated machinery (not including robotics)	75.1	85.7
Introduction or expansion of use of robotics	25.9	44.1
Introduction or improvement of quality control methods, etc.	66.2	73.0
Systems innovation (integrated factories, advanced material. handling techniques, computerized manufacturing methods, etc.)	45.1	70.7
Improvement of quality of product through worker training	48.7	73.5
Development of indirect-labor standards and controls	30.9	54.1
Other[a]	76.1	94.3

NOTE Based on a sample of 765 nonstudent Industrial Engineers in the United States

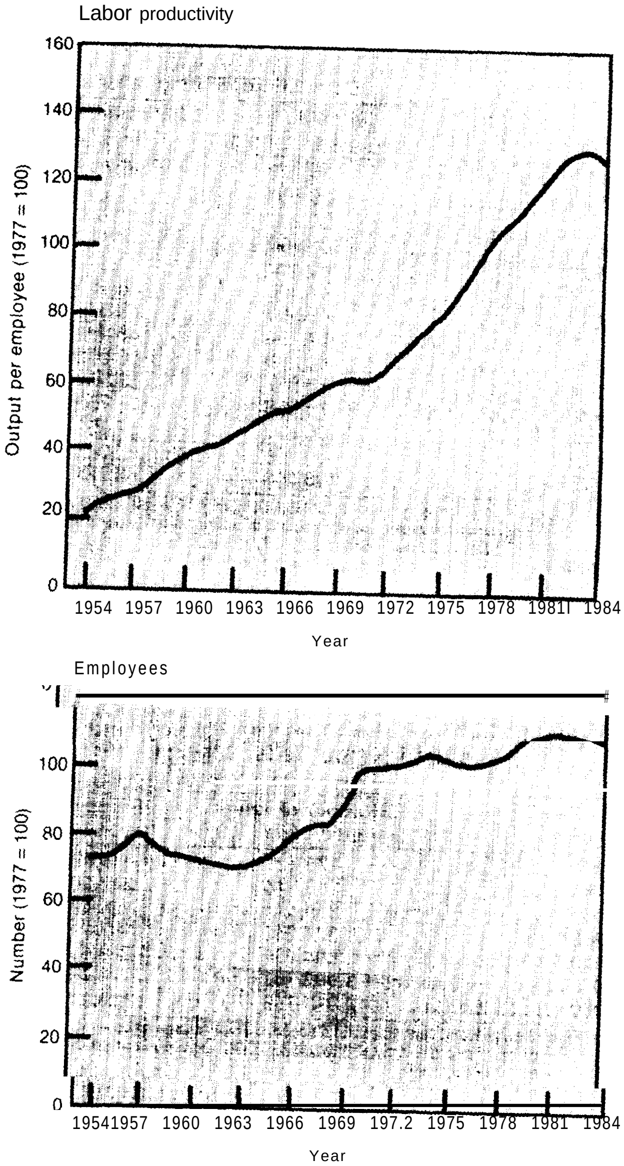
[a]The high success rate of "other" activities implies the importance of productivity efforts tailored to meet specific conditions.

SOURCE: Lane Gardner Camp, "IEs Evaluate Productivity Improvement Efforts in Own Organizations and Across U S," *Industrial Engineering*, vol 17, January 1985, p 82

1985 was about the same as in 1972, operating revenues had more than doubled in constant dollars. Output per employee hour, or labor productivity (as defined and calculated by BLS) rose 85 percent.

The remarkable changes in technology for long-distance calls has affected the composition of the work force in the telephone service industy, as well as the overall employment level, In the 30 years from 1950 to 1980, employment in the industry rose 60 percent. At the same time, while long-distance calls increased fifteenfold, operators declined from 43.5 percent of the industry work force to 14.1 percent, with an absolute loss of more than 100,000 jobs (table 8-3). Meanwhile, professional and semiprofessional jobs rose from 4.9 to 12.2 percent, business and sales jobs from 5.3 to 11.1 percent, and construction, installation, and maintenance jobs from 23.7 to 36.5 percent of industry employment.[11]

Figure 8.2.—Telephone Communications (SIC 4811)



SOURCE: US. Department of Labor, Bureau of Labor Statistics, *Productivity Measures for Selected Industries 1954-82*, Bulletin 2189 (Washington, DC: US Government Printing Office, December 1983),

Recent economic and technological changes in the telephone industry may affect the industry's relatively stable employment level of the

[11]George Kohl, *Technological Change in Telecommunications: Its Impact on Work and the Worker* (Washington, DC: Communications Workers of America, 1984).

Table 8-2.—Operating Revenues, Employment, and Labor Productivity, Telephone and Telegraph Services Industry (SIC 4811 and 4821), 1972-85

Year	Domestic operating revenues (in millions of current dollars)	Domestic operating revenues (in millions of 1972$)	Total employment (000s)	Production workers (000s)	Output per employee hour 4811 only (1977= 100)
1972	25,750	25,750	1,002	790	70.0
1973	29,600	—	1,007	780	74.6
1974	32,200	—	1,010	778	78.4
1975	35,900	—	981	748	85.9
1976	40,400	—	961	730	93.3
1977	44,100	38,150	975	738	100.0
1978	49,500	43,574	1,013	756	105.8
1979	54,754	48,957	1,070	789	110.8
1980	61,208	50,253	1,082	795	118.1
1981	70,837	53,664	1,095	796	124.4
1982	78,886	56,752	1,100	790	130.1
1983	86,870	57,952	984	720	—
1984[a]	95,700	62,345	1,010	749	—
1985[b]	106,000	65,760	1,000	745	—

NOTE: Only asmall proportion of total employment in the telephone and telegraph services industry is in telegraph services (2 percent in 1985) However, the data on operating revenues are not broken down between telephone services (SIC 4811) and telegraph services (SIC 4821). For this table, employment is reported for the two industries combined,

[a]Estimate.
[b]Forecast.

SOURCES: US. Department of Commerce, International Trade Administration, *U.S Industrial Outlook 1985* (Washington, DC: U.S. Government Printing Office, January 1985): and U.S Department of Labor, Bureau of Labor Statistics, *Productivity Measures for Selected Industries 1954-82.* Bulletin 2189 [Washington, DC: U S Government Printing Office, December 1983)

Table 8.3.—Telephone Operator Employment and Long-Distance Calls, 1950-80

Year	Number of long-distance calls (000s)	Number of operators
1950	175,721	244,190
1955	218,544	242,105
1959	365,114	198,499
1962	377,253	167,215
1970	884,285	213,614
1975	1,492,782	176,454
1980	2,641,713	128,214

SOURCE: George Kohl, *Technological Change in Telecommunications: Its Impact of Work and the Worker* (Washington, DC: Communications Workers of America, 1984).

past decade. The breakup of the Bell System by consent decree in 1982 encouraged competition that had already begun in pursuit of AT&T's long-distance markets; competitors include ITT, IBM, Northern Telecom, GTE, and Western Union. Moreover, the telecommunications and data processing industries are converging, and new technologies are developing rapidly in the combined industries. Many of these new technologies rely on digital equipment and computer software. Examples include satellite microwave communications, cellular mobile and air-to-ground telephones, electronic mail and banking, electronic credit card verification, digital paging, and automatic credit card calling.

The race to develop technologies and capture markets will continue, and the total market is expected to grow and change rapidly. The implications for employment are uncertain. While fast growing markets are usually expected to create new jobs, many of the new applications of telecommunications and data processing are highly automated already. Some technologies, such as electronic banking, have reduced the need for human labor, a trend that maybe seen throughout telecommunications. Intensified competition, moreover, may bring about job losses and displacement, In August 1985, for example, AT&T announced it would cut 24,000 jobs in its information systems division, which makes and markets communications and computer equipment. The reason given was competitive pressure and the need to cut costs.[12] Some of these jobs were in the manufacture of

[12]Mark Maremont and Michael A. Pollock, "AT&T Hangs Up on 24,000 of Its Workers, " *Business Week,* Sept. 2, 1985, pp. 35-36.

equipment, and were exported to a lower wage facility abroad (see ch, 9).

A contrary example is the plastics products industry, where no broad shift to new labor-saving technology has occurred in recent years. The plastics market grew rapidly from 1972 to 1985 as plastics replaced traditional materials (e.g., glass, paper, metal, and wood) in a broad range of products, from toys to automobile bumpers; the value of shipments rose 70 percent (constant dollars) in this period (table 8-4).

A common method of plastics product manufacture is injection molding. The job of the operator controlling the injection molding machine is an important one in the industry, accounting for about 100,000 of total industry employment of roughly half a million.[13] In most plastics plants, this job has not changed much since the early 1970s, Nor has labor productivity in the plastics products industry risen much; it increased only about 14 percent from 1972 to 1981 and did not keep up with growth of labor productivity in all manufacturing.[14] With the expansion of the plastics market and the less-than-average rise in labor productivity, employment in plastics climbed 35 percent from 1972 to 1981 (table 8-4), while the constant dollar value of shipments rose 47 percent.

Technology does exist for greater automation of injection molding and higher labor productivity. Computerized automated equipment can deliver molds and load plastic resins into the molding machine, and electronic sensors can monitor the operation throughout its cycle. Thus, in principle, the need for operators can be greatly reduced. Plants that mass produce a standard product (e.g., bleach bottles) can use highly automated systems. GE uses such a system in its Louisville dishwasher plant. The typical plastics product shop, however, is not large, and produces a variety of products in relatively small batches. Even though computerized equipment exists for batch production (capable of delivering the correct mold to the machine), few shops have installed it. Whether the

[13] The number of operators classified by BLS as compression and injection mold machine operators, plastics, was 101,000 in 1979 and 93,000 in 1982, with the decline probably due largely to the recession. Figures for this occupation for later years were not available when this report was written, Total employment in the miscellaneous plastics products industry (SIC 3079) was 488,000 in 1979 and 479,000 in 1982.

[14] James D, York, "productivity Growth in Plastics Lower Than All Manufacturing, " *Monthly Labor Review, vol.* 106, September 1983, pp. 17-21.

Table 8-4.—Trends in Output, Employment, and Productivity, Miscellaneous Plastics Products Industry (SIC 3079), 1972-85

Year	Value of shipments (millions)	Value of shipments (1972$)	Total employment (000s)	Production workers (000s)	Output per employee hour (1977= 100)
1972	10,696	10,696	346.9	276.4	86.6
1973	12,944	12,446	385.4	307,0	93.6
1974	15,190	11,702	377.5	301.6	86.2
1975	14,810	9,966	335.4	260.4	86.2
1976	18,189	11,586	375.2	295.7	89.5
1977	23,693	14,571	453.7	358.0	100.0
1978	26,796	15,922	486.6	384.8	100.8
1979	29,116	15,620	487.7	386.8	94.8
1980	30,583	14,977	470.1	368.9	95.7
1981	34,122	15,761	469.5	369.5	98.5
1982	37,029	16,672	479,2	369.1	—
1983[a]	38,350	16,932	510.1	397.7	—
1984[a]	41,575	17,691	591.1	469.8	—
1985[b]	—	18,225	—	—	—

NOTE: Miscellaneous Plastic Products (SIC 3079) is the industrial classification for the manufacture of plastic goods not classified elsewhere, This group encompasses about half the total output of plastic materials

[a]Estimate.
[b]Forecast

SOURCES U S Department of Commerce, International Trade Administration, U.S. *Industrial Outlook 1985* (Washington, DC: U.S. Government Printing Office, January 1985); and U S. Department of Labor, Bureau of Labor Statistics, *Productivity Measures for Selected Industries 1954-82,* Bulletin 2189 (Washington, DC: U S Government Printing Office, December 1983).

structure of the industry and cost considerations will remain the same over the next dozen years is unknown, so that employment estimates must remain largely speculative. If the labor-saving technology is widely adopted, employment of molding machine operators could shrink. Yet lowered costs might lead to further expansion of demand for plastics, with the effect of adding jobs in the industry–though not necessarily in the occupation of molding machine operator.

Occupational Shifts

As the example of the telephone industry indicated, technological changes that influence employment do not affect all kinds of jobs equally. Historical data on employment provide a source of insight on the links between technological change and occupational patterns. Aggregated employment data, however, are only suggestive, since factors other than technology are major causes of many occupational shifts. As chapter 9 discusses, it is difficult to separate the influences of technology, international trade, domestic competition, and changes in consumer preference on employment even in specific industries or occupations, much more so throughout the economy. For example, competition from low-wage countries may impel U.S. manufacturers to adopt labor-saving technology that eliminates many blue-collar production jobs; or companies may decide instead (or in addition) to shift some production jobs abroad. Thus the observation that production jobs have declined as a share of manufacturing jobs for several decades does not tell us directly that technology is eliminating jobs. Analysis of individual industries and occupations is needed to investigate, in each case, the importance of various factors in the rise or fall of employment.

The Past

Historical data are not complete, but changes can be tracked in broad occupational groups. The groups are professional and technical workers, such as scientists, engineers, technicians, purchasing agents, and accountants; managers and administrators; salesworkers, such as sales clerks and agents; clerical workers, such as office clerks, secretaries, keypunch operators, and bookkeepers; craft and kindred workers, such as carpenters, mechanics, machinists, and typesetters; operatives, such as assemblers, machine tool operators, production painters, and forklift operators; nonfarm laborers, such as pipelayers, helpers, and highway maintenance workers; service workers, such as building custodians, waiters and waitresses, flight attendants, and barbers; and farmworkers.

The 2Oth century has seen major changes in employment by occupation. Most notable is the decline in prominence of farmworker jobs. The number of farmworkers fell from 37,5 percent of the work force in 1900 to less than 3 percent in the 1980s (table 8-5, figure 8-3). The change stemmed from the mechanization of agriculture and other advances in technology (e.g., the development of new crop varieties and the rapidly increasing use of commercial fertilizers and pesticides), as U.S agricultural production tripled and productivity rose elevenfold during the period.

Since World War II, the number of production workers in manufacturing industries has also declined relative to the total work force, although more moderately. Both the relative share of manufacturing jobs in the economy and the relative share of production jobs in manufacturing have declined (figures 8-4 and 8-5). Within manufacturing, the proportion of production workers went from 84 to 69 percent between 1947 and 1984. From 1979 to 1985, manufacturing employment dropped absolutely as well, by over 1.7 million jobs. Nearly all of the jobs lost were those of production workers.[15]

The unskilled occupation of nonfarm laborer has declined sharply in this century, from 12.5 percent of U.S. employment in 1900 to 4.6 percent in 1980. With growing industrialization in the first half of the century, operatives (most of them semiskilled manufacturing workers)

[15] See ch. 4 for a discussion of employment trends.

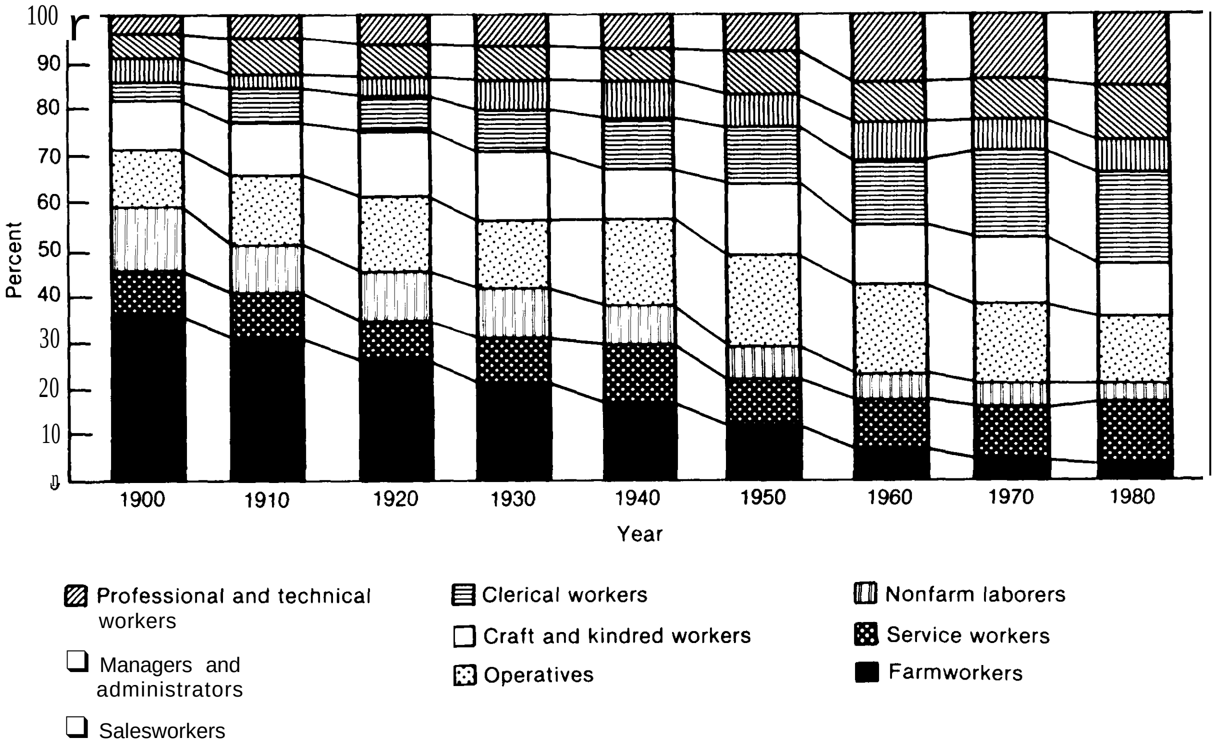
Table 8-5.—Percentages of Total U.S. Employment Accounted for by Major Occupational Groups, 1900-80

Occupational group	1900	1910	1920	1930	1940	1950	1960	1970	1980
Professional and technical workers. . . .	4.3	4.7	5.4	6.8	7.5	8.6	10.8	14.5	16.1
Managers and administrators	5.8	6.6	6.6	7.4	7.3	8.7	8.1	8.1	11.2
Salesworkers	4.5	4.7	4.9	6.3	6.7	7.0	7.1	7.0	6.3
Clerical workers	3.0	5.3	8.0	8.9	9.6	12.3	14.1	17.8	18.6
Craft and kindred workers.	10.5	11.6	13.0	12.8	12.0	14.2	13.6	13.9	12.9
Operatives	12.8	14.6	15.6	15.8	18.4	20.4	18.9	18.0	14.2
Nonfarm laborers ... , ...	12.5	12.0	11.6	11.0	9.4	6.6	5.2	4.7	4.6
Service workers.	9.0	9.6	7.8	9.8	11.7	10.5	11.2	12.8	13.3
Farmworkers	37.5	30.9	27.0	21.2	17.4	11.8	6.0	3.1	2.8

NOTE Figures are approximate, due to changing classification systems See sources for details

SOURCES U.S Department of Commerce, Bureau of the Census, *Historical Statistics of the United Slates,* Part 1 (Washington, DC: U.S. Government Printing Office, 1975), and U S Department of Labor, Bureau of Labor Statistics, *Employment and Earnings*, January 1981)

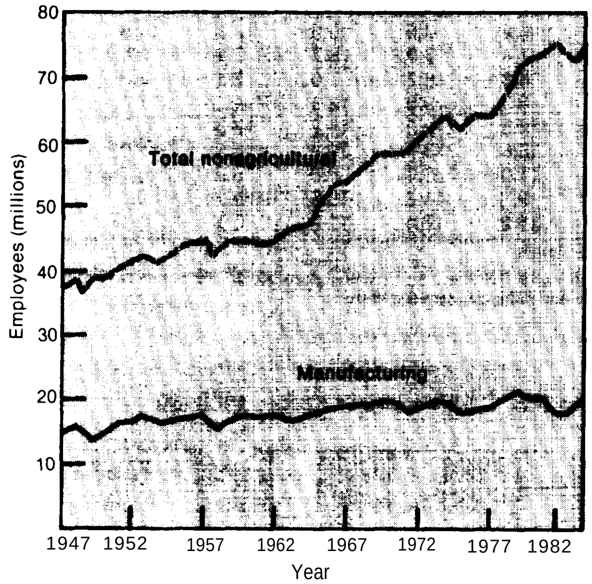
Figure 8.3.–Major Occupational Groups of the U.S. Civilian Labor Force, 1900-80



NOTE: Figures are approximate, due to changing classification systems See sources for details.

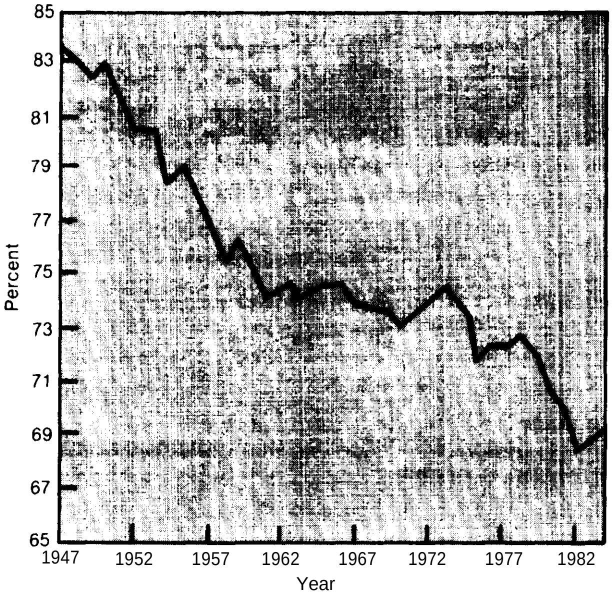
SOURCES. U S. Department of Commerce, Bureau of the Census, *Historical Statistics of the United States*, Part 1 (Washington, DC: U.S. Government Printing Off Ice, 1975); and U.S Department of Labor, Bureau of Statistics, *Employment and Earnings,* January 1981).

Figure 8-4.—Total Private Nonagricultural and Manufacturing Employment, 1947-84



SOURCE. U.S. Department of Labor, Bureau of Labor Statistics, Employment and Earnings.

Figure 8-5.— Production Workers As a Percent of Total Manufacturing Employment, 1947-84



SOURCE: U S Department of Labor, Bureau of Labor Statistics, Employment and Earninas.

rose to 20.4 percent of all workers in 1950, but fell thereafter to 14.2 percent. The proportion of skilled blue-collar craft and kindred workers also declined, but less steeply. The most remarkable occupational increases were those of clerical workers (rising from 3.0 to 18.6 percent of the work force from 1900 to 1980) and of professional and technical workers (rising from 4.3 to 16.1 percent),

Even though forces other than technology contributed to occupational shifts from 1900 to 1980, and even though occupational titles changed their meaning over these years, technology has apparently created demands for more highly skilled workers, and diminished demands for less skilled workers, in this century.

The Present and Near Future

This report and other recent OTA assessments have found that the technological advances now taking place favor the continuation of some but not all of the occupational trends of past decades.[16] Computer-based technology is transforming many kinds of work, and is a major factor in shifting demands for some skills, groups of skills, and occupations to others. Several general patterns are emerging:

- In manufacturing, where about 18 percent of employed Americans now work, job opportunities will probably rise for technicians, mechanics, repairers, and installers, as well as for engineers and computer scientists.
- Employment opportunities in manufacturing will probably fall for all production workers. This includes operatives, especially those doing the most routine work; laborers; and many metalworking craft-

[16] U. S. Congress, Office of Technology Assessment, *Computerized Manufacturing Automation: Employment, Education, and the Workplace,* OTA-CIT-235 (Washington, DC: U.S. Government Printing Office, April 1984), ch. 4; U.S. Congress, Office of Technology Assessment, *Automation of America Offices, 1985-2000,* OTA-CIT-287 (Washington, DC: U.S. Government Printing Office, December 1985), ch. 2.

workers, such as machinists and press operators. Job openings for lower and middle managers may also fall.

- In offices, where 40 to 45 percent of workers are employed, growth in job opportunities will probably slow down over the next few years and by the 1990s may begin to decline. Specific jobs most likely to decline are those for clerical workers, especially where the main tasks are entering and transferring data, Employment opportunities may also shrink for lower and middle managers.[17]

The finding for clerical workers indicates a break with the past. With the rapid diffusion of office automation, clerical worker jobs may undergo the kind of downturn experienced by operatives since 1950. The OTA report Automation of Americia Offices, 1985-2000 found that computers are a fundamental technological change, as telephones and typewriters were —not just a marginal improvement.[18] Overall it appears that the trends of past decades toward greater demand for professional and technical workers and slackening demand for manufacturing production workers will continue or perhaps accelerate, In manufacturing, the effects of computer-based and other advanced technologies on occupational patterns probably reinforce the effects of international competition (see ch. 9). Both forces put the jobs of production workers, especially the semiskilled and unskilled, at risk.

Many industries illustrate the point. A leading example is the motor vehicle industry, responding to pressure from foreign competition by large capital investments in new equipment, redesign of products, and reorganization of plants and firms. The end result is fewer jobs in planning and scheduling, in moving parts around the factory, and in painting, welding, and assembling automobiles, In many plants, robots already apply sealant and paint and do spot welding; automated materials handling nearly eliminates the need for human forklift operators. Jobs for factory clerks decline as computer-controlled just-in-time delivery systems are installed. The potential for further reduction of semiskilled jobs appears high, New body designs (as in the Chrysler minivans) facilitate assembly by robots and also reduce the number of parts that have to be assembled. Automation of testing and inspection implies further losses of job opportunities for semiskilled workers.

Besides the much-publicized robots and other forms of computerized automation now being adopted in auto manufacture, less noticed but significant changes in conventional equipment have eliminated some semiskilled jobs.[19] For example, new coatings for machine tool cutting edges can double the cutting speeds, thus improving productivity and reducing demand for machine operators. Quick die change presses are more expensive than conventional equipment and are used mainly where dies have to be changed frequently; but these presses can be operated by one worker at a master control panel—compared to at least six on conventional presses.

Some skilled production workers, such as machinists and tool and die makers, in autos are also being displaced. In the future, as computerized equipment becomes more reliable and electronic diagnosis is increasingly available, maintenance and repair workers may be less needed. Among technical occupations, drafting is declining. For the present and near

[17] Overall employment in offices—just as in manufacturing and in specific industries—is determined by other factors besides technology, most significantly product demand. By lowering costs, changing the services offered, and improving quality, technological advance can help to raise demand for the services provided by office workers (e. g., banking, financial services), as it does for manufacturing products. Thus, if overall demand rises enough, the employment-dampening effects of technology on office jobs may be offset. This does not affect the conclusion that among office workers, the clerical worker job is most at risk from technological advance.

[18] The Bureau of Labor Statistics, in its occupational employment forecasts, takes a more gradual view of the effects of office automation and indicates continued growth in office employment. An evaluation of the way BLS generally takes technological change into account in its occupational employment forecasts appears in app. 8A of this chapter. The OTA report *Automation of America Offices, 1985-2000* evaluates the BLS method for handling technological change in relation to office automation. Ibid.

[19] See U. S. Department of Labor, Bureau of Labor Statistics, *The Impact of Technology on Labor in Four industries*, Bulletin 2228 (Washington, DC: U.S. Government Printing Office, 1985).

future, prospects for employment growth in production are favorable for electricians and mechanics, repairers, and installers, but the increased demand for craft and technical workers will be less than the reduction in demand for operatives.

The textile industry, like the auto industry, is under intense pressure from foreign competition, and many of the larger mills are responding with rapid adoption of automated machinery.[20] Federal regulations limiting cotton dust levels to protect workers' health may also have contributed to the rapid pace of modernization. In modern mills, a continuous opening-blending-carding operation (known as direct-feed carding) both raises productivity and meets the cotton dust regulations.

Unskilled and semiskilled jobs dwindle in the modern direct-feed carding plant. The semiskilled job of picker operator is eliminated, and there is no need for laborers to move fiber laps from one separate machine to the next. Also, labor for cleaning and maintaining the machines is reduced, since cotton dust levels are lower. Spinning, the final step in yarn manufacture, is also being modernized as open-end or rotor spinning replaces ring spinning. The modern machine integrates several processes that were separate (roving, spinning, and winding), can outproduce the conventional spindle four or five times, and do it with less semiskilled and unskilled labor. In weaving, shuttleless looms average two to three times the output of conventional looms and thus require fewer operators. Demands for skilled technicians have risen in modernized plants; shortages are reported in some areas.

In the aerospace industry—aircraft, missile and space, and avionics (electronic communication, control, and monitoring equipment)—technological advances also appear to be reducing jobs for production workers.[21] However, demand for the product is a more obvious and powerful influence on both total employment and production jobs. Table 8-6 shows a clear pattern of rises and falls of production jobs in aerospace depending on sales—from highs of over $30 billion in 1968 and 1983, when military aircraft purchases were large, to a low of $21.5 billion (constant 1972 dollars) in 1977.

Nonetheless, as is typical for high-technology industries, the proportion of production workers is lower than the all-manufacturing average, and is declining. Aerospace is by any definition a high-technology industry, with a ratio of research and development expenditures to net sales at least twice the average for all industries and a relatively high proportion of technology-oriented workers.[22] From 1972 to 1982, growth in the industry's spending for new capital averaged 23 percent per year—nearly as high as in the computer industry. This rate compares, for example, with a growth rate in capital spending of less than 10 percent in the automobile industry during the same period.[23] The proportion of scientists, engineers, and technicians in the work force is high–over 25 percent in 1985.

Production workers accounted for only 45 percent of the aerospace industry work force in 1985, compared with 68 percent in manufacturing industries overall. The share of production jobs in aerospace employment has declined from 52.6 percent in 1968 (table 8-6). Although numbers on employment losses related to technological change in the industry are elusive, it seems likely that the industry's widespread adoption of numerically controlled (NC) equipment since the late 1960s has been a factor in the relatively low and declining level of production jobs.

NC machine tools were introduced in the aerospace industry in the 1950s, partly because

[20] Ibid.; see also U.S. Department of Commerce, International Trade Administration, 1986 U.S. *Industrial Outlook* (Washington, DC: Department of Commerce, January 1986), p. 42-2. See ch. 9 for discussion of the effects of international trade on textile industry employment.

[21] Information in this section was drawn from OTA staff visits to an aerospace manufacturing plant and publications of the U.S. Departments of Labor and Commerce and the Aerospace Industries Association of America, as cited below.

[22] For definitions of high-technology industries and data on their employment, see U.S. Congress, Office of Technology Assessment, ***Technology, Innovation, and Regional Development,*** OTA-STI-238 (Washington, DC: U.S. Government Printing Office, July 1984), The aerospace industry is included under all definitions, including the most restrictive (ratio of R&D spending to sales twice the average).

[23] U.S. Department of Commerce, International Trade Administration, *1986 U.S. Industrial Outlook,* op. cit., pp. 28-8, 36-4, 37-13.

Table 8.6.–Aerospace Industry Employment by Occupational Group, 1968-85

		Employees							
Year	Sales (in billions of 1972$)	Total (000s)	Production workers (000s)	Percentage of total	Scientists and engineers	Percentage of total	Technicians	Percentage of total	All others
1968	30.1	1,403	738	52.6	221	15.8	81	5.8	363
1969	27.9	1,295	658	50.8	203	15,7	72	5.6	362
1970	26.5	1,069	528	49.4	167	15.6	67	6.3	307
1971	22,3	924	448	48.5	159	17.2	60	6.5	257
1972 ., ...	21.5	944	473	50.1	168	17.8	65	6.9	238
1973	23.4	962	484	50.3	164	17.0	66	6.9	248
1974	23.1	973	483	49.6	166	17.1	67	6.9	257
1975	22.4	925	444	48.0	167	18.1	63	6.8	251
1976	21.7	898	420	46.8	166	18.5	62	6.9	250
1977	21.5	894	410	45.9	173	19.4	59	6.6	252
1978	22.6	1,032	519	50.3	170	16.5	64	6.2	279
1979	24.8	1,152	592	51.4	177	15.4	69	6.0	314
1980	27,9	1,218	612	50.2	196	16.1	78	6.4	332
1981	29.6	1,203	578	48.0	194	16.1	84	7.0	347
1982	29,4	1,153	535	46.4	200	17.3	79	6.9	339
1983	30.8	1,171	528	45.1	207	17.7	87	7.4	349
1984a	—	1,252	567	45.3	223	17.8	93	7.4	369
1985a	—	1,299	584	45.0	234	18,0	98	7.5	383

NOTE" Data based on December survey. Industry strikes occurred in 1977 and 1983 Employment figures include aircraft, missile, and space industries (SIC 372 and 376); estimated aerospace-related communication equipment (SIC 3662) and instruments (SIC 381 and 382); and estimated related products (SIC 28,35,73,89, etc)

[a]Estimates.

SOURCE: Aerospace Industries Association, *Aerospace News,* Washington, DC Apr. 19, 1985; and Aerospace Industries Association, *Aerospace **Facts** and **Figures*** 1984/85 (New York" Aviation Week & Space Technology, 1984).

they were able to meet demanding specifications for military orders (which account for 50 to 70 percent of the aerospace business). In addition, the automated tools save the production labor of skilled and semiskilled machine operators. Other NC applications reduce the need for several kinds of semiskilled production labor. For example, NC pipe-bending machinery eliminates the need for time-consuming measuring and bending of pipes by humans, NC riveting improves quality and reduces the number of riveters required for a given job. Fiber-optic cable and new cockpit designs promise to reduce the need for a range of production work in electrical wiring, from the semiskilled job of cutting wires to specified lengths to the more skilled tasks of wire-splicing and routing.

The employment figures in the aerospace industry suggest some of the difficulties that production workers losing jobs in manufacturing now face. Displaced production workers who want to remain in the same industry will need training to qualify for one of the growing technical occupations. Yet there are not enough of these jobs to go around, Between 1968 and 1985, technical jobs in aerospace grew by 30,000, while jobs for production workers dropped by 154,000.

TECHNOLOGICAL CHANGE AND THE NATURE OF JOBS

Technological change affects not only the number of jobs but also their nature. Skills may become obsolete, new skills may be demanded, and the content of particular jobs may be altered. If automation simplifies or de-skills a job, wages for that kind of job may fall; or the job may become mechanical and stultifying. On the other hand, new technologies may open possibilities of more interesting, better paid jobs, at least for those workers with the skills to qualify.

Concerns about the effects of technology on the nature and quality of jobs and the skills required for them are not new. As factory automation was adopted in the late 1950s, many people expected not only that factory employment would fall but that blue-collar workers would have to acquire higher skills to deal with the new equipment. With the rapid economic growth and falling unemployment rates of the 1960s, these concerns diminished. Some skills and occupations were obviously affected—those of compositors, for instance, as typesetting was computerized, or longshoremen, with changes in packaging and containerization. Many of the affected workers were represented by strong unions, which won comfortable settlements for those who were displaced. More generally, the strong economic growth and rising real wages of the 1960s eased readjustment problems.

Today, the debate on what technology is doing to skill requirements has reappeared and now extends to white-collar and service workers as well as blue-collar workers. Two opposing points of view are prominent—that technological change leads to upgrading of skills, making for better jobs but also requiring more training or education, so that less skilled people may have trouble finding jobs; or, on the contrary, that advanced technology de-skills jobs, making them narrower, more repetitious and perfunctory, and leaving workers as nothing but machine tenders at relatively low pay. A third view has also emerged: that technological changes are increasing the quality and number of some higher level jobs while eliminating or downgrading middle-level positions, thus creating a skills gap between lower and higher level jobs.

Framed in this way, the arguments are overly simple. First, they focus too narrowly on the relation between skill levels and wages, leaving out of account the powerful influence of economic conditions; and second, they take too narrow a view of technology, assuming that the equipment and hardware alone determine what jobs will be like.

The differing economic conditions of the 1960s and the 1980s illustrate the importance of the first factor. If some kinds of factory work were de-skilled by the automation of the 1960s (an arguable assertion), the prosperity, low unemployment rates, and rising real wages of that decade more than compensated most workers. Also, in some manufacturing industries, collective bargaining contributed to higher pay than might have been expected for workers with limited skills or education. By the mid-1980s, by contrast, real wages of production and nonsupervisory workers on private nonagricultural payrolls had been declining for more than a decade. In 1985 hourly earnings of these workers were about 6 percent below their earnings in 1977 (in constant dollars); weekly earnings had dropped 9 percent below the 1977 level, and were about 14 percent below their highest point, in 1972 and 1973. The reasons had less to do with changes in the skill content of jobs, associated with technological change, than with a number of economic and social factors—the entrance of millions of inexperienced young people and women into the job market in the 1970s, the inflation of the late 1970s, the deep recession of the early 1980s, the persistence of unemployment in the mid-1980s at rates above 7 percent, the decline of labor unions, and intense competition from lower wage countries. In this situation, with real wages on the decline and unemployment rates high by historical standards, the effect on wages of de-skilling a large number of jobs might prove considerable.

Also missing in the de-skilling/upgrading argument is the point that technology alone does not determine the nature of jobs. It does not, by itself, raise, lower, or polarize the skills required. While the characteristics of a new technology, and the competitive environment of the firm or industry adopting it, set limits, there is usually room for some latitude in redesigning jobs. In organizing the tasks that remain for human workers to do, managers and engineers (sometimes with worker participation) may have a range of options, from rationalizing jobs—i.e., reducing them to simple, repetitive tasks—to broadening and integrating jobs, that is, including more kinds of tasks in each job and establishing for each a goal that is the logical culmination of the set of tasks, A wide range of options does not always exist; costs and other constraints are important. Also, it is often difficult to foresee exactly what options there may be with new, unfamiliar technologies. Nonetheless, as examples in the following sections show, different solutions are possible with some jobs; upgrading and deskilling of essentially the same job are occurring in different firms and countries.

OTA's analysis does suggest some commonality in the skills that will be needed in factories, offices, and services such as health care to make effective use of advanced technologies. These skills differ from the ones that many displaced workers possess. Routine mental and physical skills (e.g., those used in operating machines, moving materials, punching keyboards) will be less in demand. More in demand will be good basic competencies in reading and math, a broad understanding of how the individual worker's tasks and job fit with those of others, an aptitude for team work, and an ability to get the feel for, and take responsibility for, the proper functioning of expensive equipment in complex production systems.

Technology and the Range of Job Options

How Technology Displaces Jobs

Even though technology alone does not determine the makeup of jobs, it is a major force in determining the range of possible job options. Its main effects are: 1) to displace tasks previously performed by people; 2) to create new tasks; and 3) to limit, by its inherent features, the ways in which tasks can be allocated to specific jobs.

New technologies can displace the tasks of human workers in several ways. The most obvious way is for a machine to take over a task performed by a worker. Robots that load workplaces into automated machine tools, for example, take the place of the human worker, but the task still exists. Another common form of technological displacement is a change in process or product that eliminates the task. Some plastic parts, for example, need hand finishing to remove flash (excess material) from the finished product. A different molding technique, used for some parts, prevents the flash from forming, thereby eliminating the finishing operation. The task of hand finishing is not automated; it is no longer needed. Tasks may also disappear when technology changes the demand for a product. For example, when hand calculators replaced slide rules, several specialized precision machining and printing tasks disappeared.

Tasks, or parts of jobs, are more commonly displaced than entire jobs; work is restructured to use new technology, in some cases leaving fewer people performing the same amount of work. For example, a law firm may employ five lawyers, all of whom spend part of their days searching for legal references. When the firm introduces a computer to identify sources, the laywers can do more work of other kinds. If four lawyers can handle as many cases with a computer as five could without the computer, one lawyer can be displaced. The computer, however, does not possess the skills of a lawyer. In the same way robots, no matter how adroit they become, do not replicate human workers.

Often, new technologies both displace and create tasks. For example, automatic material-handling equipment displaces the manual task of driving a delivery cart and most of the loading and unloading tasks. At the same time, it requires computer programming, machine monitoring, and maintenance.

The design of technology may limit or expand the options for allocating tasks. The positioning of workstations on an assembly line, for example, limits the tasks that can be assigned to any one person, since a worker cannot perform tasks at two distant stations at the same time. New technology may also broaden options. A case in point is advanced electronic equipment, which allows an airplane pilot to perform navigational tasks. These examples illustrate the fact that many of the features of a new technology which limit or expand options for assigning tasks are designed into the technology. Design choices are not unconstrained. They are limited by physical possibility, scientific understanding, engineering know-how, traditional ways of thinking, and, most significantly, by costs. Even so, the effects of technology on the tasks workers perform arise from the decisions made by people, from the early stages of research, development, and design, to the end point of use of the new equipment or methods in the workplace.[24]

How decisions made in the design stage affect jobs is illustrated by a recent Swedish effort in which workers cooperated with computer scientists to develop a new printing technology. Computerized text entry, typesetting, and layout have made far-reaching changes in the number and quality of jobs for production workers in printing. Making up pages for newspapers was once the province of printers on the shop floor, in the days of lead type. Today it is becoming a computer terminal job. By 1980, the Swedish Graphic Workers Union, representing printers, typographers, lithographers, and other production workers in printing, sought a role in developing software that skilled workers could use as an advanced tool in making layouts.[25] Instead of leaving the technology design solely to vendors and computer scientists, the workers wanted a say in research and development, to support technology that would make use of their skills, create desirable working conditions, and contribute to higher product quality.

With the help of public funding, the union formed a cooperative program with government and business called Project UTOPIA (in Swedish, an acronym for training, technology and products from a skilled worker's perspective). The project developed a computer and software system that allows the operator to visualize on the computer screen both full-page layouts and close-ups of details. This feature gives the operator greater power to design interesting layouts than other computerized layout systems, which do not show the actual page on the screen. According to the workers, an operator who has to "work blind" without seeing how the page will look is less able to create an attractive, varied layout. Another benefit of the union's involvement was that it gave participants a broader understanding of the potential of computer technology in printing.

The labor-management-government cooperation of the UTOPIA project is rare. Even in Norway, where laws guarantee union involvement in technological planning, unions are more likely to wait until new systems are designed and implemented before making a critical assessment. It is nearly always managers, guided by technical experts, who make the major decisions on the design and use of new technology.[26]

People and Machines

There are limits to replacing human labor completely with technology. Three kinds of considerations influence the mix of human beings and technology in producing goods and services: 1) technological constraints: the fact that some tasks cannot be done well, or economically, or at all by mechanical or electronic means; 2) the need for people to design, operate, maintain, and repair technology; and 3) the selection of some tasks for people to perform because the tasks are important to quality of worklife, or tradition, or aesthetics, despite proven abilities of machines to perform those tasks.

In assigning responsibility among humans and machines, engineers and managers often view people as adjuncts, available to do whatever is too complex or too expensive to automate. Some regard people as unpredictable, demanding, and inefficient compared with machines, and see automatic manufacturing as an opportunity to design humans out of the system. People are not so easily dispensable, how-

[24] For a comparative study of the work-related priorities of engineers and computer systems designers in the United Kingdom, Sweden, and the United States, see: Bo Hedberg and Enid Mumford, "Design of Computer Systems"; and J.C. Taylor, "Job Design Criteria Twenty Years Later," in *Design of Jobs,* 2d cd,, L, II. Davis and J.C. Taylor (eds.) (Santa Monica, CA: Goodyear, 1979), pp. 44-53 and 54-62, respectively.

[25] Robert Howard, "UTOPIA: Where Workers Craft New Technology," *Technology Review*, vol. 88, No. 3, 1985, pp. 42-49.

[26] Leslie Schneider, "Technology Bargaining in Norway," *Technology and the Need for New Labor Relations,* Discussion Paper Series, John Fitzgerald Kennedy School of Government, Harvard University, August 1984.

ever. While technical advances have enabled machines to take over some of the work people did in the past—with improvements in productivity and reductions in costs—it is seldom possible to do without human judgment and flexibility.

Human skills are rarely directly comparable with those of machines. Descriptions of what people can do as if they were machines (mechanistic models of skill) and descriptions of what machines can do as if they were people (anthropomorphic models of technical performance) fail to capture the great versatility of human labor. A robotic system, for example, may include visual sensors to locate objects and an electronic controller to respond to this information. Yet this system does not begin to match the complexity and adaptability of human perception, thought, and action. People are much better than machines at work requiring judgment, interpretation, and adaptability. When a nail hits a knot, a carpenter can adjust. Current generations of robots cannot. A computerized vision system can spot solder runs on a printed circuit board but cannot interpret X-rays of pipeline welds. Confusion over what people do well and what machines can do well leads to poorly designed jobs and machines. z'

Automated systems, while they may run with fewer people, still require some people. When computers are integrated with complex systems—in process control, for example—performance of tasks does not become wholly automatic (see box 8A). The same is proving to be true in automated systems for small-lot production.[28]

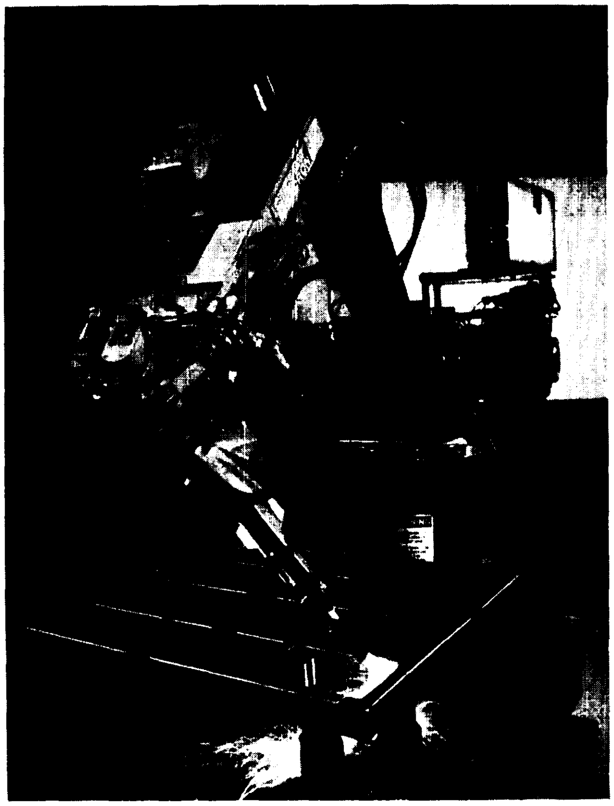


Photo credit: Cincinnati Milacron

Industrial robot welding a computer frame assembly

Automated systems cannot be idiot-proofed. In fact they are likely to be more sensitive than labor-intensive systems; one unexpected occurrence can shut down a highly automated process. Moreover, when heavily stressed, faced with unusual conditions, automated systems may fail in unexpected ways, throwing the decisions back on human operators. All too often, as in the Three Mile Island accident, the people have trouble coping—perhaps because their jobs have been poorly designed.[29] As jobs in automated systems become more routine under normal circumstances and more demand-

[27] K. Noro and Y. Okada, "Robotization and Human Factors," *Ergonomics*, vol. 26, October 1983, pp. 985-1000; H. McIlvaine Parsons and Greg P. Kearsley, "Robotics and Human Factors: Current Status and Future Prospects," ***Human Factors,*** vol. 24, October 1982, pp. 535-552; and Warren P. Seering, "Who Said Robots Should Work Like People?" ***Technology Review,*** vol. 88, April 1985, pp. 59-67.

[28] See, for example: Robin P. Bergstrom, "Taking Stock of FMS . . . Users Speak Up," ***Manufacturing Engineering,*** vol. 92, March 1984, pp. 48-55; "Roundtable Participants Talk About CIM Myths and Realities, People Aspects and the Future," *Industrial Engineering*, vol. 17, January 1985, pp. 35-51.

[29] For a list of operator limits on automated systems, see Christopher D. Wickens, ***Engineering Psychology and Human performance*** (Columbus, OH: Charles E. Merrill Publishing Co., 1984), pp. 490-495. For a discussion of work design issues at Three Mile Island, see Joel A. Fadem, "Automation and Work Design in the United States," ***Automation and Work Design,*** F. Butera and J.E. Thurman (eds.) (Amsterdam: North Holland, 1984), pp. 647-696.

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of wear or looking for other potential malfunctions. The tender also has chief responsibility for a variety of manual operations not directed by the computer, including changing filters and aligning equipment. In emergencies, such as malfunctions in the paper machine, the machine tender's ability to diagnose the trouble rapidly, coordinate the crew, and possibly direct activities of other workers as well become crucial. Much of his time, however, is spent in the control room—a haven from the noise, heat, and fumes of the mill floor, and a place for socializing with other crew members when the work load ebbs.

The work of the other crew members also involves traditional blue-collar tasks, requiring dexterity and skill in the use of hand tools. At least one, sometimes more, members of the crew are trained in the machine tender's job so they can substitute if needed. Members are also trained in each other's tasks. Traditionally, crew members were expected to monitor the machine's operation with a combination of skills and art based on experience (e.g., a crew member might taste the pulp to evaluate its acidity). In some automated mills, crew members are expected to keep up these skills, in case the machinery fails.

The machine tender's job was always one of the best in the mill. A worker might spend 25 years in various mill jobs before moving up to tender. In one highly computerized mill, managers required formal training, provided onsite in an initial 20-week intensive course, followed by further training. The initial course was open to all applicants who qualified whether or not they were current employees; at the end of it, candidates for machine tender were chosen primarily on the basis of their training test scores. In selection systems of this kind, on-the-job training still has some value, in preparing the tender for responsibility and giving him a broad understanding of related jobs in the mill. But the abstract character of monitoring and troubleshooting complex equipment puts a premium on classroom instruction.

ing when complex systems malfunction, operators may have more trouble diagnosing system problems in an emergency, just when quick and correct response is vital.

In general, highly automated systems demand greater responsibility by employees and depend more heavily on human judgment and skill than do more traditional systems. Whether the job is that of a nuclear powerplant operator or an air traffic controller, man-machine integration becomes more crucial as the capabilities of the machine expand. One implication is that the distinctions between managers and production workers narrow as the latter take on greater responsibilities.

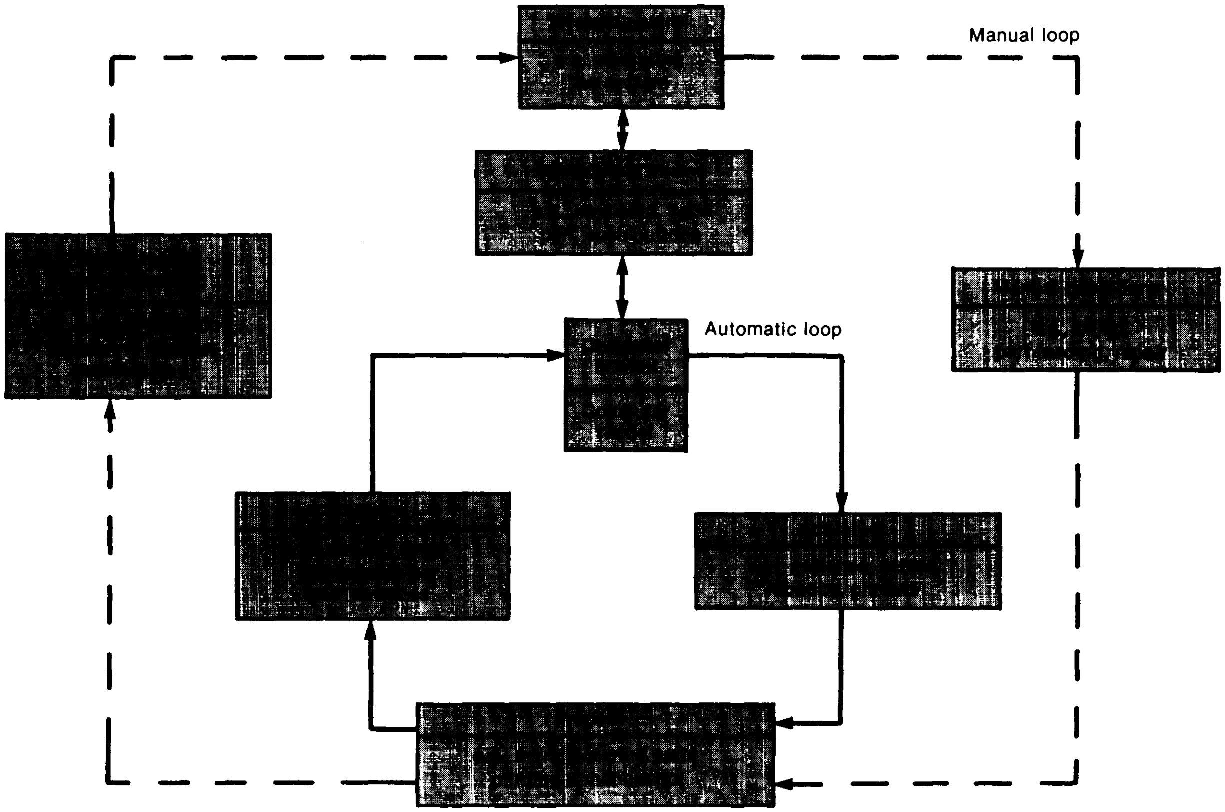
Task and Skills Changes

As new technologies are adopted in the workplace, cognitive and communication tasks will be shared by workers and computers, and people will share tasks of observation and physical manipulation with sensors and mechanical actuators or manipulators. Because some kinds of tasks are more suited to the capabilities of machines than others, jobs made up mostly of such tasks may be vulnerable to displacement.

Figure 8-6 depicts a semiautomatic system in which human workers and machines both perform tasks. Human-operated manual commands and computer commands can both control the work. In the automated loop, the computer model, a collection of algorithms and specifications of acceptable operating conditions, sends directions to actuators. Sensors continuously enter data on changes in the work environment, keeping the computer model current. The manual loop allows worker control of the system through an input-output device to the computer model. People regulate the work process through manual testing and observation, and manipulate it by operations such as part loading or repairs (see box 8A).

As figure 8-6 indicates, the greater the reliance on sensors, actuators, and the computer model, the less the need for the corresponding human tasks, Computer algorithms displace

Figure 8-6.—Control Network for a Semiautomatic System



SOURCE: Office of Technology Assessment.

the human tasks of routine organization and transfer of information, and also well-defined computational tasks, such as daily production planning, accounting, and correspondence. Mechanical sensors can take the place of some sensory and perceptual tasks, and mechanical actuators displace tasks requiring manipulative skills.[30]

The riveting of airplane skins illustrates some of the ways in which tasks are assigned to humans and machines with computerized technology (see box 8B for details). Riveting, a fastening task traditionally done with a hand-held riveting gun, can also be performed with a computer-controlled machine. The correct procedures for positioning and driving rivets come both from stored information in the computer and from the operator's knowledge. Electronic sensors and the vigilance of the operator protect the process from poor rivets and machine malfunctions. Many (not all) of the manipulative tasks shift to the riveting machine, but human operators gain some new cognitive tasks, such as avoiding uncorrected program errors, stopping the machine in case of malfunction, and doing minor troubleshooting. Other workers—skilled maintenance people—must be familiar with the machine and knowledgeable about computer and electronic instrumentation.

Hospital technical workers provide another example of changing tasks and changing skill

[30] See, for example, Stephen G. Peitchinis, *Computer Technology and Employment: Retrospect and Prospect* (New York: St. Martin's Press, 1983), p. 98.

Box 8B.—Numerically Controlled Riveting Machine Operator—Airplanes[1]

Riveting, a semiskilled production job, is important in airplane manufacture, where rivets fasten together aluminum sections of the fuselage and wings. Traditionally the job was performed with a hand-held riveting gun. The use of numerically controlled (NC) riveting machines is common among major aircraft manufacturers today. With the new technology, the skills required for riveting have shifted from primarily manual to more mental and conceptual, although in both the old and new technologies there is a mix of manual and mental skills.

Up until World War II, airplane riveting was done mostly by hand. Workers with hand-held riveting guns inserted rivets according to prepared layouts. This labor-intensive process was expensive and physically demanding. Wrist ailments, hearing loss due to high noise levels, fatigue, and injuries from working in cramped quarters were not uncommon. Stress related to the work sometimes led to fist fights on the shop floor.

Wartime production and a shortage of workers encouraged the development of riveting machines—manually operated at first, and later numerically controlled.[2] These machines improved the quality and consistency of riveted joints and reduced the cost. Hand methods have not been entirely superseded; they are used for about 10 percent of the rivets on a large commercial airplane. Places that are hard to get at where a machine would not fit, small oddly shaped pieces, final assembly points such as joining wings to fuselage, and repairs of bad rivet joints still call for a riveter experienced with a hand-held riveting gun.

Manual (non-NC) riveting machines were the first replacement for the riveting gun, and are still generally used to rivet smaller subassembly pieces of the airplane. Responsibilities of the machine operator include set-up of the machine, operation, quality control, and coordination of work with others involved in the manufacturing process. From his experience as a hand riveter, the operator has gained a familiarity with the size and kind of rivet for each job, which he may need for selecting rivets or for detecting errors. The operator also needs the ability to judge the quality of a riveted joint. Additional training for operating a non-NC machine usually amounts to 2 days of formal training and 1 week of on-the-job training at the machine.

Before each different part and between changes in rivet size or type the machine needs to be set up or adjusted. The operator analyzes the work required, selects the correct rivets and tools (e.g., drills, anvils, hoppers), and makes minor adjustments to the machine, including changes for different rivet sizes. Aluminum parts or subassemblies, usually light enough for the operator to lift and handle, are generally delivered with the rivet positions marked on them. The operator aligns the marks with the target position of the machine and presses a foot pedal to activate the drilling-countersinking-riveting sequence. On some machines, a laser highlights the target area, which adds to the positioning accuracy.

The operator is responsible for checking his own work and may spot problems from earlier stages. For example, if an operator notices that the marked position for riveting a rib deviates from patterns seen in the past, he may question the layout rather than proceeding with riveting—perhaps preventing a costly error. The operator also marks any bad rivets he may make, so they can be corrected later by hand.

For an NC machine, the operator performs the same setup tasks as those for manual riveting machines, plus new tasks. Usually the structures to be riveted are too big for the operator to handle, and are positioned by hydraulic equipment. The operator positions the workpiece correctly relative to the riveting machine, selects and aligns tools, loads the NC tape or disk, and runs a test coupon (two small aluminum sections riveted together to test the machine's operation). With an NC machine,

[1]Based on an OTA case study at Boeing Commercial Airplane Co., Seattle, WA. February 1985.

[2]For a history of riveting, see: Walter G. Vincenti, "Technological Knowledge Without Science: The innovation of Flush Riveting in American Airplanes, ca. 1930-ca. 1950," *Technology and Culture*, vol. 25, No. 3, 19S4, pp. 540-578.

[illegible]

[illegible]

Communication skills are essential to the job in other ways as well. Changes in specifications, additions to the work flow, [illegible] several other people [illegible] neers and maintenance personnel. These social skills, often overlooked, are necessary for all involved to work well together and to manufacture a quality product.

While maintenance technicians tackle the more difficult equipment problems, the NC machine [illegible]. The operator, with time, develops an [illegible] feel for the operation of a given machine—its [illegible] and coordinate this understanding with the others responsible for the machine to ensure smooth operation. These include engineers, maintenance workers, planners, foremen, NC programmers, and technicians.

The skill requirements of the NC riveting machine operation are clearly different than those of hand riveting or even non-NC machine riveting. The knowledge gained in hand riveting (e.g., rivet selection, quality inspection) does transfer to the more automated jobs, but there is a major shift from manual to more conceptual skills. The NC operator must deal with complex changes and possible malfunctions which are beyond the realm of hand riveting. He is removed from physical contact with the workpiece, and must have a more [illegible] model of the work. Instead of feeling in his arm the impact of inserting a rivet, he observes it, from 20 feet away, on a television screen.

Perhaps the most telling evidence of the shift away from physical skills is the attitudes of operators. At one aircraft plant, the area containing the NC riveting machines is jokingly called the "rest home." Notably, the area is quiet. Manual rivets are inserted with impact force, while the automated technique squeezes them in with steady pressure. The vibration of the riveting gun, the muscle fatigue, the bending, crouching, and standing required for manual riveting are replaced with an office chair before the controls.

requirements with advances in technology, as described in an OTA contractor report.[31] Medical technologists test blood and other body fluids for a number of factors, including the presence of chemical substances and disease-producing organisms, number and characteristics of white and red blood cells, blood type and clotting time, and the status of the body's immune system. Credentials for medical technologists include a bachelor's degree in biology or chemistry. These workers are expected to decide whether test results are valid, to grasp the significance of patterns of daily test results for individual patients, and to alert physicians to potentially life-threatening conditions. They also need manual skills for laboratory bench work with such equipment as pipettes and bottled reagents.

[31] Bernard Ingster, Charles P. Hall, Jr., and Arnold I. Silverman, "Effects of New Technology on Skill Requirements of Clinical Laboratory Technologies and Radiologic Technologists," contractor report prepared for the Office of Technology Assessment,

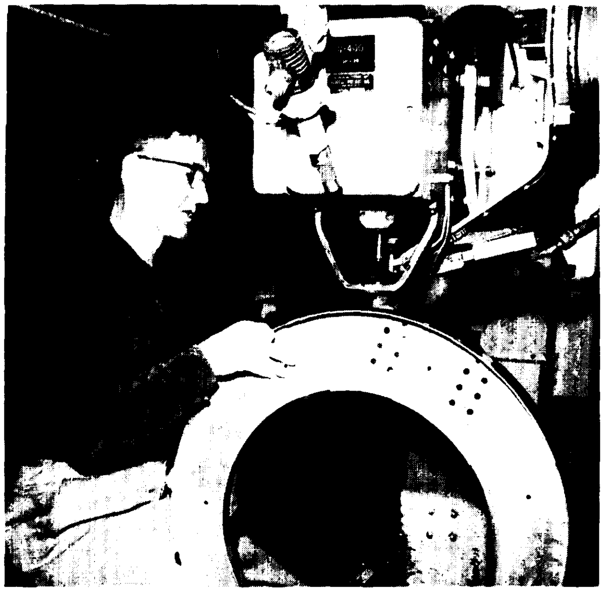


Photo credit: Gemeral-Electro Mechanical Corp.

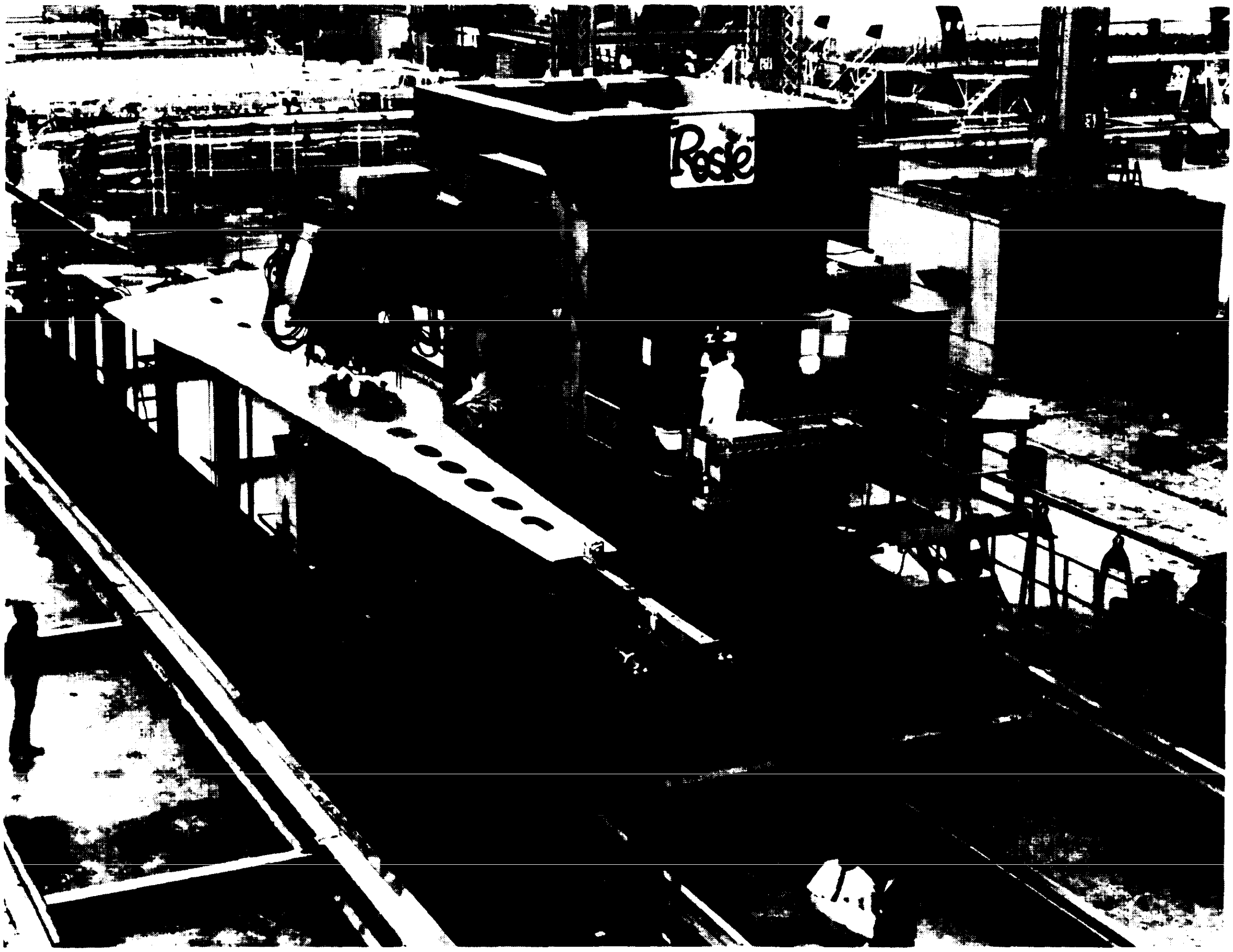
Worker operating a riveting machine

In clinical chemical laboratories, where technologists test blood for chemical substances, most of the work is done with fast, automated, computerized equipment. Automation of the work began in the 1950s and has become increasingly more sophisticated. Technologists in modern labs need only type in the test selection on a computer keyboard, load the specimen, and push a button. The equipment can determine whether a sample is out of normal range and redo the test automatically, and can record and transmit results to other workstations. Technologists retain responsibility, however, for validating test results. If they are out of the normal range, and the technologist feels that the process was faulty, he/she must run the test again. Or, the technologist may determine that the tests are a valid indicator of the patient's health. Technologists are also expected to retain their manual skills for occasions when physicans want independent confirmation of an automated test result and, more rarely, in case of emergency failure of the automated equipment. In common with factory workers using automated equipment, these laboratory workers must have enough understanding of the equipment to spot malfunctions and do simple troubleshooting. Table 8-7 summarizes the changing tasks of both clinical lab technologists and radiologic technologists with the introduction of new equipment.

Despite the steady rise in labor productivity of clinical laboratory technologists, employment of medical technologists approximately quadrupled from 1966 to 1982, increasing from 38,000 to 150,000. Exactly comparable data for hospital beds and patients are not available, but the ratio of full-time hospital employees to patients in hospitals rose from 2.24 in 1965 to 3.76 in 1982, and medical technologist jobs were part of that growth. The reason was the rapid introduction of new technologies and services, especially after Medicare and Medicaid laws were passed in 1966. It is expected that budget stringency and cost containment for both Medicare and Medicaid will now sharply curtail the rate of hospital employment growth.[32] Total hospital employment has in fact dropped slightly since 1983. In one of two hospitals studied by OTA's contractor, employment in clinical laboratories dropped slightly from 1979 to 1984, but attrition took care of the reductions; there were no layoffs. In the other hospital, clinical lab employment has remained stable; it may expand, since the hospital is discontinuing some work once performed by an outside commercial laboratory and bringing that work into its own labs.

Changes in skill requirements for radiologic technologists show a different pattern from that of clinical lab technologists, where the emphasis is on further automation of existing diagnostic services. In radiology, the new technologies are linked with significant advances in the physician's diagnostic abilities. With conventional X-rays, the way to visualize different segments of the body is to rotate the patient or the equipment and take several pictures, In the newer technology of computed tomography (CT) the body part is placed within a ring of multiple X-ray sources, which are linked to electronic systems that capture multiple images. Computers process the images and inte-

[32]Ibid., Section B.



O m

grate them for visual display on monitors or film. CT scanners are able to take extremely thin cross-sectional "slices" of the head and body, at different angles, and produce crisper images than the conventional X-rays. CT has been in use for about 10 years.

A still newer technology is magnetic resonance imaging (MR). Like CT, it produces cross-sectional images generated by computer; but in contrast with X-ray technologies, it produces clear images of soft tissues without obstruction by bone. The main component of the technology is a powerful, ring-shaped magnet, which is fitted closely around the head or body part of the patient,

Both CT and MR do something new and different from conventional X-rays; they supplement, not supplant, the older technology. The tasks associated with conventional X-ray are not displaced, but new ones are added (table 8-7). The old and new tasks usually are not performed by the same people, however; CT and MR technologists are usually specialists who have been given further training after qualifying in conventional radiologic techniques. Employment of radiologic technologists is not ex-

Table 8-7.—The Changing Tasks of Medical and Radiologic Technologists

Work tasks	Displaced tasks	Unchanged tasks	Created tasks
Medical technologist:			
Understanding chemical test reactions sufficiently to assess the quality of manual testing processes	X	X	....
Having the manipulative skills to perform laboratory bench tests	X	X	....
Maintaining quality standards during manual testing	X	X	....
Confirming changes during manual testing by visual inspection	X	X	....
Performing manual testing according to strictly defined protocols and "self-review" of work	X	X	....
Understanding the significance of a pattern of results of daily testing of a patient	....	X	....
Confirming and validating test results.	....	X	....
Observing the results of the process being performed to ensure correct protocols are followed	....	X	....
Determining when to inform physicians of a potentially life-threatening situation.	....	X	....
Maintaining quality standards during instrument testing	....	....	X
Determining if results produced by automatic instruments are valid	....	....	X
Understanding the operating systems, protocols, work flow, and maintenance practices for diverse automatic instruments.	....	....	X
Having the manipulative skills to control automatic equipment	....	....	X
Monitoring the information on cathode-ray tubes and test data recorded by automatic equipment.	....	....	X
Identifying the kinds and probable sources of malfunctions of automatic instruments	....	....	X
Raidologic technologist:			
Understanding conventional X-ray procedures, with particular attention to body positioning and film exposure techniques	X	X	....
Using good interpersonal skills in working with patients and physicians	....	X	....
Having the manipulative skills in working with equipment and patients	....	X	....
Reviewing of X-ray film to assure that the desired body area has been filmed and that the film quality is as specified by the physician	....	X	....
Determining proper body position and exposure parameters for X-ray imaging of the "target" body area	....	X	....
Deciding whether the target area is filmed as requested	....	X	....
Following highly detailed procedures	....	X	....
Understanding cross-sectional anatomy	....	....	X
Understanding the operating characteristics of the computed-tomography (CT) scanner	....	....	X
Understanding the operating principles of the magnetic resonance (MR) scanner	....	....	X
Understanding how the CT or MR equipment accommodates body positioning and exposures automatically	....	....	X
Showing more sensitivity in interpersonal relationships with patients who must be confined for a long period in small areas	....	....	X
Reviewing of MR image films that do not show bone structures.	....	....	X
Determining that the CT or MR equipment is operating correctly	....	....	X
Determining whether a cross-sectional anatomy image has been filmed as requested by a physician	....	....	X
Identifying the nature of malfunctions in CT or MR equiptment	....	....	X

SOURCE Off Ice of Technology Assessment, based on Bernard Ingster, Charles P. Hall, Jr , and Arnold I Silverman, "Effects of New Technology on Sk Ill Requirements of Clinical Laboratory Technologists and Radiologic Technologists, " contractor report prepared for the Office of Technology Assessment, October 1984 pected to decline, but to continue growing moderately.

CT and MR require rather less skill in positioning the body than conventional X-rays, since they produce their images from multiple sources. They both require understanding of cross-sectional anatomy and the ability to recognize whether the image on a monitor is satisfactory, as well as familiarity with how the new equipment works. In the case of MR, technologists must understand the basic principle of the technology and the power of the magnet; they, as well as physicians and nurses, must be aware of the potentially fatal hazard to a patient with metallic implants in his body. Both CT and MR technologists need interpersonal skills to help put patients at ease during lengthy procedures (up to an hour) -especially in the case of MR, which may require a patient to keep his head immobile in a small, tight container. Like other workers using computerized equipment, MR and CT technologists must be alert to equipment malfunctions. They must know when the trouble is beyond making a few simple adjustments, and when to call in the repair specialist.

Changes in the nature of work in computerized offices have features in common with those of factories and hospital laboratories. A recent study of automation in French banking concluded that workers in computerized systems need to use higher order conceptual skills, to form a mental model of how the system works.[33] The study found that, while automation lessened some of the traditional skill requirements for data entry clerks, it also required new and qualitatively different skills. A grasp of banking and computer operations became more important with automation, and the growing interdependence of parts of the system heightened the need for cooperation among the clerical workers. At first, these qualitative shifts in skill requirements were not recognized. When the French banks originally computerized, managers simplified jobs and reduced training requirements. However, they soon found that the clerks' isolation and lack of understanding of how the system worked were causing errors, lowering productivity, and making customers angry. In response, French banks had to make major investments in retraining clerical workers, particularly in basic computer literacy, the structure of the bank's processing system, and the logic of bank accounting.[34] The unexpected result of computerization was that low-level clerical jobs became more important to maintaining the quality and efficiency of banking operations as a whole.

The analysis of French banking is one of several studies suggesting that individual responsibility, ability to coordinate work with others, and decisionmaking skills increase as both service and manufacturing jobs are automated.[35] New technologies based on computer systems tend to displace routine mental and manual tasks, and in some cases displace tasks requiring more complex skills, such as operation of machine tools. At the same time, they add requirements of human operators for judgment, evaluation, the ability to spot problems and either solve them or call on specialists to do so, and an understanding of how one's own tasks and job fit into the larger picture. A grasp of basic statistical concepts–an understanding of trends and limits—will be needed for many jobs for better quality control. Social skills–ability to communicate readily and work with others as a team-often take on increasing importance.

Many of the general skills needed for working with computerized systems are transferable from one job to another. These skills are provided, at least in part, by a good basic education that teaches quantitative, verbal, reasoning, and social skills. For many displaced workers and adults currently in the labor force, remedial education in reading, simple mathematics, and elementary scientific and practical technical principles may be needed if they

[33] Paul Adler, "Rethinking the Skill Requirements of New Technologies," Working Paper, Harvard University Graduate School of Business Administration, 1983.

[34] Ibid., p. 24.

[35] F. Butera, "Designing Work in Automated Systems: A Review of the Case Studies, " *Automation and Work Design,* F. Butera and J.E. Thurman (eds.) (Amsterdam: North Holland, 1984), pp. 43-105.

are to work effectively with advanced technologies (see ch. 7). In many cases, the new technologies require highly skilled maintenance workers. Workers selected for training in maintenance and repair work are likely to be those with a good basic education. For these workers, a knowledge of secondary school mathematics, electronics, and computers will be valuable assets.

Some observers interpret the changes involved with advanced technologies as moving toward simpler, narrower, less-skilled tasks for human workers. In the earlier wave of automation, beginning in the late 1950s, many people expected that the automated factory would require increased skills, more training, and better education of workers, Bright's 1957 case studies of the metalworking, food, and chemical industries indicated that, after a period of heightened skill requirements in the early stages of automation, the level of skills required of operators diminished with the growth of computer control and greater reliability of automated equipment. so

Bright also found that automation did not greatly increase the need for skilled maintenance workers. Like operators of the machines, maintenance people might need higher skill levels to debug a first, unique piece of automated equipment, but at a later stage few special skills would be required to maintain the more advanced and reliable equipment. Some analysts expect that computer-based technologies will follow a similar pattern. They argue that after computer programs have been tested and debugged and operations become more stable, the skills required of everyone, from operatives to maintenance workers to engineers, are likely to decline. However, if the pace of change is accelerating, as many analysts believe, then learning periods will recur at shorter intervals.

In any case, computerized technologies will require skills that are qualitatively different from the skills needed to work with older technologies. One recent survey of advanced technologies in manufacturing describes the shift as follows:

> The direction of manufacturing skills changes is from physically involved, manipulative, tactile, "hands on" type of work to that which is conceptual, cognitive, and based on an abstract understanding of the process. Instead of maintaining close physical contact with the product and with the process through touch, sight, sound and smell, the production worker stands aside while the integrated combination of computers and machines proceeds with minimal direct human intervention. In one job of this kind a worker loads a workpiece into a computer-controlled machining center and starts the machine. For the next 7% hours, while the machine makes the myriad cuts required, the worker merely attends the machine, intervening only once, about 4 hours into the process, to re-orient the part on its fixture . . . The workpiece is large and valuable, as is the machine. A broken tool, a loose fixture, a defect in the workpiece, or a "glitch" in a computer program could cause thousands of dollars of damage in a few seconds. The worker is monitoring the process rather than being part of it.[37]

The same study found that the need for skilled maintenance workers is declining as the connection between computer and machine becomes closer. Diagnosis of trouble and prescribed remedies may be provided by a computer located far from the factory.

Some of these examples raise broader issues than whether different kinds of skills are needed for new technologies. They put the question of raised or lowered skill requirements into the context of how jobs are redesigned as part of technological change, and whether job quality is enhanced or degraded, The following section discusses this subject,

Redesigning Jobs as Part of Technological Change

When new technologies are introduced into a factory or office, the ways in which tasks are rearranged into new jobs have a critical influ-

[36]James R. Bright, "Does Automation Raise Skill Requirements?" *Harvard Business Review*, July-August 1958, pp. 85-98.

[37]Robert T. Lund and John A. Hansen, *Keeping America at Work: Strategies for Employing the New Technologies (New* York: John Wiley & Sons, 1986), pp. 93-94,

ence on the nature of the jobs. The pattern of tasks can determine whether the new jobs are de-skilled or upgraded, whether they contain variety or are narrow and repetitious, whether they involve broader responsibilities or are confined to an isolated aspect of the firm's business, and possibly whether they provide opportunities for growth and advancement to better jobs.

As with other aspects of new technology, managers and technical experts make the major decisions on how tasks are to be reorganized into jobs. The primary objective of managers in these decisions is efficiency—minimum cost consistent with constraints such as product design, production volume, capital spending limitations, and enough flexibility to accommodate changes in design or production volume. It is not always simple and obvious, however, what kinds of job design and work organization are most conducive to efficiency. Often, when new equipment is brought in, no one specifically considers the range of options for rearranging jobs; and it maybe hard even to foresee all the options. Options that would change the jobs of many people may be rejected because it is easier to stick with established procedures and areas of responsibility. Nor is there any uniform answer for all businesses. Different companies choose different strategies for achieving efficiency, and these choices may in turn lead to differing choices in the design of jobs and organization of work, even with the same equipment. Decisions about job design may also reflect other important factors, such as training and abilities of the work force, national policies on quality of work life, relations with labor unions, and the politics of the workplace.[38] Examples in this section illustrate some of the latitude and some of the constraints in job design. A later section discusses innovative organization of work that some companies are adopting together with technological advances.

With the introduction of numerically controlled (NC) machine tools, for example, new and old tasks may be allocated among jobs in a number of different ways. With traditional machine tools, a machinist operates one machine. His responsibilities include deciding how a part is to be cut, selecting cutting tools and work-holding fixtures, and determining the cutting speed for each workpiece. The job also is likely to include making adjustments during the cutting operation; continually checking for tool wear, vibration, and malfunctions; and measuring the part for accuracy. The finished workpiece is the machinist's responsibility. The use of NC machines alters this traditional set of tasks. Most of the planning (selecting the cutting tools and work-holding fixtures) is taken over by the NC programmer; so is the determination of cutting speed. Monitoring tasks, such as making adjustments and checking for malfunctions, remain for the machine operator, although their character may be changed somewhat. New tasks include programming and operating the NC controls and monitoring more than one machine.

In an analytic review of studies describing how jobs were restructured and work reorganized after the introduction of computerized numerically controlled (CNC) machine tools, Kelley found a wide range of solutions, with no single pattern predominating.[39] The range was from de-skilling, to upgrading of jobs, to a polarization of jobs in which one machine operator took on the new tasks of programming, proofing out (testing the program) and editing, and the rest found their jobs de-skilled.

One study of U.K. and West German plants found that programming tasks were often added to the machinist's job, especially in small-scale operations. Another study of five U.K. plants found that in each case a programmer had ex-

[38] See, for example, L.E. Davis and J.C. Taylor, "Technology Effects on Job, Work and Organizational Structure: A Contingency View," ***Quality of Working Life Volume One: Problems, Prospects and the State of the Art,*** L.E. Davis and A.B. Cherns (eds.) (New York: The Free Press, 1975), p. 220-241; David F. Noble, *Forces of Production: A Social History of Industrial Automation (New* York: Knopf, 1984); Harley Shaiken, ***Work Transformed: Automation and Labor in the Computer Age (New*** York: Holt, Rinehart & Winston, 1984).

[39] Maryellen R, Kelley, "Programmable Automation and Production Workers' Skills: An International Comparison of Management Practices, " Working Paper WP 86-002 (Boston: College of Management, University of Massachusetts at Boston, October 1985).

elusive charge of planning, testing, and editing the programs—so exclusive that in two plants the control cabinet for the editing machine was locked, and only programmers and supervisors had the key. A third pattern in U.K. plants was for programmers to have sole charge of all programming functions at the outset, but over time, for operators gradually to assume responsibility for proofing out and editing.

According to Kelley's analysis, job redesign varied in U.S. plants. Analyzing four of Shaiken's case studies of shops where CNC machine tools were used, she concluded that in one, machinist jobs were definitely de-skilled; here, operators were not allowed to change the program or perform any major setup tasks.[40] In another case, a modest size plant specializing in small-batch production, CNC operators did not create programs, but set up their own machines, and also proofed out programs. In the latter capacity, the operators kept some informal control over the technology by offering suggestions to the programmer. In the other two plants, blue-collar workers created, proofed out, and edited CNC programs—but in both these cases only one worker wrote programs (in one plant, a CNC lathe operator, and in the other, a machine repairer/millwright). In one of these plants, some of the operators set up their own machines and did some proofing out and editing of programs. Kelley's own observations at another two U.S. plants showed similar variation; in one, machinist jobs were definitely de-skilled, with no responsibility for programming or setups. In the other, operators were expected to fine-tune the programs.

Studies of how automated flexible manufacturing systems (FMSs) have been managed in different countries illustrate the range of choices in designing jobs around a more complex advanced technology. They also shed some light on the factors, besides those directly related to efficiency, that influence the choices.[41] One study of FMS in three countries (the United States, Japan, and West Germany) found that strategies of firms differed by country, with West German firms strongly emphasizing flexibility, U.S. firms giving higher labor productivity top priority, and the Japanese combining emphasis on quality improvement with both flexibility and higher labor productivity.[42] As the firms' strategic goals differed, so did the definition of jobs and organization of work.

An FMS is a production unit made up of semi-independent workstations, connected by automated material handling systems and controlled by computer, which is designed to manufacture different kinds of parts in relatively small batches. The system typically includes NC machining centers, loading stations, and robots or conveyors to move materials; it may also have other workstations such as automatic inspection devices, FMS units are frequently used to make parts for automotive equipment—e.g., transmission case and clutch housings for tractors, or turbine engine components for military tanks; but the FMS can also be adapted to manufacture of robots or NC machine tools, as in the famous Fanuc Ltd. factory in Japan, where machine tools operate at night with no one on the machining floor and only one worker in a control room. When designed and used appropriately, the FMS offers two major advantages: 1) the capacity for nearly full-time use of expensive NC machine tools; and 2) the ability to produce small batches of parts or products economically, because setup costs are minimal for later batches once a first batch has

[40]Kelley, four case studies, for which descriptions of the organization of machining work were provided, from H, Shaiken, S. Kuhn, and S. Herzenberg, "Case Studies on the Introduction of Programmable Automation in Manufacturing," vol. II, part A in U.S. Congress, Office of Technology Assessment, *Computerized Manufacturing Automation,* op. cit.

[41]See for example, T. Martin (cd.], *Design of Work in Automated Manufacturing Systems*, Proceedings of the International Federation of Automatic Control Workshop, Karlsruhe, Federal Republic of Germany, November 1983 (New York: Pergamon Press, 1984), including A. Alioth, "Flexible Automation and Job Design in Manufacturing Systems: Conclusions From a Visit to Japan, " I. Asendorf and Schultz-Wild, "Work Organization and Training in a Flexible Manufacturing System—An Alternative Approach, " and A. D'Iribarne and B. Lutz, "Work Organization in Flexible Manufacturing Systems—First Findings From International Comparisons"; see also Ramchandran Jaikumar, "Flexible Manufacturing Systems: A Managerial Perspective, " Working Paper 1-784-078, Harvard Business School, Division of Research, 1984.

[42]Jaikumar, op. cit.; Alioth in Martin, op. cit.; D' Iribarne and Lutz, op. cit.

been programmed and produced. These two qualities of high utilization of machines and flexibility are not altogether consistent; one may have to be sacrificed to some degree to the other.

Jaikumar's exploratory survey examined about 70 percent of the systems operating in the world in 1981, with closest attention to the 26 FMS installations then operating in the United States. (There are currently about 50 FMS installations in the United States.) The study concluded that the systems were most flexible-in the sense of adapting quickly to variations in products and volume-in West Germany. The number of parts made in German FMS units ranged from 50 to 200, with a mean of 85. In the United States, the average number of parts made per installation was 8, and in Japan, about 30.

In the United States, Jaikumar's study found that FMS was usually managed as a project with a beginning and an end, not as a continuing process. A team of experts, generally provided by the vendor, installed the system. After a debugging period when engineers and programmers solved software and production problems, further changes tended to be minimal. The goal in most installations was maximum use of the machines with little downtime and high labor productivity; job design featured routine, repeatable tasks. Typically, the machines did not require the skills of master machinists but could be run by less skilled operators, whose duties included changing hydraulic fluid, oiling machinery, changing parts such as drill bits, checking gauges, using the computer terminal for routine checks, and making simple diagnoses when something went wrong. Electrical and mechanical maintenance people were trained to follow a disciplined set of procedures with little deviation from the manual.

Flexibility in the German systems appears to depend greatly on the interaction between man and machine. The German FMS units are usually run with a small crew of highly skilled workers who received special training in all aspects of FMS tasks, including basics of NC control, NC-machine and robot programming, detection of faults, and work scheduling. These crews work two shifts; for the third shift, less-skilled workers only monitor the machines. The quality brought to the system by the highly skilled human workers is versatility and ability to solve problems. Using a rather general software structure, they make adjustments based on their own knowledge which is "idiosyncratic, not perfectly reproducible, and not transferable."[43]

The Japanese firms typically pursue a strategy of using FMS units both for improving quality and for gaining the flexibility to schedule short-term variations in products and volume. (In addition, as shown by the unmanned operation of night shifts in FMS units, the Japanese also apparently aim both for higher labor productivity and for a demonstration of their technical prowess.) The design of jobs is consistent with these combined goals. Japanese FMS units have two classes of workers: about five highly qualified operators in each unit doing controlling tasks, and one or two less skilled workers whose tasks are feeding and taking off parts. Operators take part in creating software for the systems, evaluating it from a practical point of view as engineers develop it—the two often working alongside each other on the factory floor. This system gives the operator enough understanding of the program that he can make corrections or adjustments during production. To qualify for an operator position, workers need a good education, which they now get in Japan's public high schools. Because of the educational requirements, FMS operators are mostly young people recently out of school. Older machinists, trained through apprenticeship to work on conventional machine tools, are rarely retrained for the NC centers in FMS units.

Several factors have apparently affected the choice of strategies and job design in the early installation of FMSs in these different countries. For example, German national policy supports projects to improve the quality of work life; a pioneer FMS project in West Germany, installed in an automotive parts plant of a large

[43]Jaikumar, Op. Cit., p. 32.

manufacturing company, was sponsored by the German Ministry for Research and Technology, Integral to the project was a nonhierarchical organization of work using a skilled, versatile crew. Besides government support, the project benefited from an ample supply of skilled production workers, the product of West Germany's highly developed apprenticeship and industrial training system. Whether such a system is adaptable to other countries is an open question; indeed whether it will prove profitable in West Germany is uncertain.

Japan's use of FMS also reflects its national institutions and traditions. The rigorous technical and scientific education offered in public schools produces well-qualified workers prepared to learn and use high-level skills in FMSs. A relatively broad definition of jobs is also typical of the practice in many Japanese manufacturing firms. In the United States, the tradition of designing factory jobs with narrow, strictly defined tasks is long-standing. The American version of early FMS installations found in Jaikumar's exploratory study was in this tradition.

Management decisions about the redesign of jobs as new equipment is brought in can have decisive effects on job quality. For example, a computerized system to handle customer requests for telephone repair caused job dissatisfaction for the clerks who operated it[44] The management goal was to speed operations and reduce the number of clerks needed to take customer requests and dispatch maintenance crews. Under the old system, clerks in local repair centers received requests from customers, recorded details on a form, initiated a manual test of the customer's telephone service, made a tentative date for the repair and handed the form to the supervisor of the repair crew. In the new computerized system, clerks were relocated to a few answering centers. They no longer communicated directly with the repair crew, but entered information from customers' requests by keyboard into a centralized computer system. The computer instantaneously dispatched the data to the appropriate repair center and at the same time started an automatic check of the customer's service.

The new system was not only unpopular with workers but had some unexpected bad effects on performance. The clerks worried about job security and were dissatisfied with the boring nature of the work (mostly data entry), the physical confinement, and the loss of personal contact with customers and repair workers. Performance suffered from errors and delays because most of the clerks were inexperienced with keyboards, and had not been adequately retrained. The physical separation of answering clerks and repair crews led to jurisdictional disputes, and also to a loss of responsiveness to customers' individual needs. Reacting against the new system, some employees resorted to tactics that undermined it. At one busy repair center, workers discovered that an idiosyncrasy in the computer program allowed them to erase the record of a customer's call—which they proceeded to do at the end of their shift, giving the next shift a clean slate and also frustrating customers who never got a reply to their service calls.

In other cases, managers have designed more interesting, responsible jobs around new technologies—usually because they expect better employee performance and greater overall efficiency as a result. For example, in the letter of credit department of the First National Bank of Boston, one person at a computer terminal can now review documents, create a file, send a letter, and authorize payment. This series of jobs was formerly performed by a chain of clerks. Under the new system, wages in this section of the bank have been raised, and the position is "sometimes a way station in the officer-training program."[45]

Shenandoah Life in Virginia was able to streamline operations with the use of a new computer system—but only after a period of using the computer less effectively.[46] At first,

[44] Trevor A. Williams, "Technological Innovation and Futures of Work Organization: A Choice of Social Design Principles," *Technological Forecasting and Social Change*, vol. 24, 1983, pp. 79-90.

[45] Bob Kuttner, "The Declining Middle," *The Atlantic Monthly*, July 1983, p. 64.

[46] John B. Myers, "Making Organizations Adaptive to Change: Eliminating Bureaucracy at Shenandoah Life," *National Productivity Review*, Spring 1985, pp. 131-138,

the routine operation of converting a customer's multiple insurance policies into one universal policy was organized assembly-line fashion. Even with the computer, it took 32 people in three departments 27 days to complete the process. With a decision to organize the operation differently, six team members participated in designing their own office layout, salary system, and the work within their team. The new organization, coupled with the new computer systems handled a 13-percent increase in business without additional employees, service complaints and errors declined.

Human factors are a constraint on the ability of management to upgrade or downgrade jobs. For example, reorganizing work may involve trespassing on traditional turf within organizations, and encounter resistance. Quality of work and productivity may ultimately decline if individual judgment is removed from work. If a software package controls all decisions, workers may be less willing to spot and correct errors, try more effective approaches, or aim for higher quality.[47] Lack of appropriate skills in the labor force can also limit organizational choices.

The examples in this section indicate that the decisions made in task allocation can affect the occupational mix in the work environment, the skill level and scope of particular jobs, and the degree of training required for particular jobs. How tasks are reassigned to jobs and workers as new technology is introduced has important implications both for the skill requirements of jobs and for retraining needs.

[47] Shoshana Zuboff, "New Worlds of Computer-Mediated Work," *Harvard Business Review*, September/October 1982, p. 147.

TECHNOLOGY AND THE ORGANIZATION OF WORK

In any business, things run like clockwork only some of the time. Other times, parts of the system threaten to go out of control. Factories of almost any type are complex systems, often chaotic and messy. For instance, at any particular time a job shop producing components and assemblies to order will have a certain number of jobs in process. The lot sizes will differ, as will the required materials. In addition, the shop may have a queue of jobs waiting to enter the process flow. It will have a certain stock of machine tools and production equipment, with partially overlapping capabilities. Machinery and equipment that in principle can be assigned a given job will produce parts that are qualitatively different (e.g., a milled surface versus one produced by a shaper or a surface grinder). Operating costs will differ depending on the equipment used. More highly skilled operators may be needed for some machines and for some tasks than for others. The shop can subcontract work, and may have to for specialized operations such as plating or high-quality welding. Add to these factors such imponderable as machine breakdowns and late deliveries of materials and supplies; the result is a factory of some complexity,

One response to this complexity is to break down jobs into simple, narrow clusters of tasks, and to attempt to keep the potential for human error to a minimum. Work is arranged so that each person need learn and perform only simple tasks such as installing a taillight lens on a car, monitoring the dials on a control panel, or loading a program into an automated machining center.[48] How these tasks are to be accomplished—e.g., whether to use red lighting for the dials—becomes the job of the expert, commonly an engineer or industrial psychologist. The same building block approach is used to organize the work of the whole enterprise. Departments organized by specialized activity take responsibility only for their own functions (e.g., drilling, grinding, heat treatment, painting and finishing, materials handling, shipping, maintenance, and repair). One group of people designs and develops the product. Another group lays out factories and specifies the manufacturing operations, A third group supervises production employees.

[48] See S.A. Konz, *Work Design* (Columbus, OH: Grid Publishing, 1979); B.W. Niebel, *Motion and Time Study*, 7th ed, (Homewood, IL: Irwin, 1982); A. Chapanis, *Man-Machine Engineering* (Belmont, CA: Wadsworth, 1965).

Despite its appeal of simplicity and order, this approach may not lead to minimum cost or to maximum productivity and efficiency. Even assuming that simplifying jobs makes for greater efficiency (an assumption that has proven untrue in some enterprises), maximum efficiency in individual tasks or jobs, or in subsystems in isolation, need not result in an optimum for the system as a whole.

Different forms of work organization—where jobs include a variety of tasks and call on a broader repertory of skills, worker groups have more responsibility, and work is organized around the product rather than in specialized departments and subsystems—have been advocated as both improving worklife and leading to greater productive efficiency. In what circumstances new forms of work organization can satisfy both these objectives is not clear. Often the objectives of job satisfaction and organizational efficiency are compatible, but not always and not necessarily.

The benefits of new forms of work organization may be hard to trace. Most companies, when they introduce such systems, do so to improve efficiency, defined broadly. However, companies that have adopted them, and consider them successful, usually do not reveal details, for competitive reasons. Thus, quantitative information on efficiency improvements is difficult to obtain.

There is a another reason as well for the lack of concrete data on benefits of new organizational design. For substantial departures from past practices, conventional accounting measures may not capture the full range of benefits. Even in cases that seem on the surface straightforward, such as improved inventory control, direct cost reductions give only part of the picture. For example, in the Japanese companies that have pioneered minimum inventory systems, part of the benefit is indirect: reducing inventory to low levels exposes bottlenecks elsewhere in the system. Minimum inventory becomes a tool for improving system performance, but cost accounting seldom captures such benefits.

In general, evidence that participative systems of work organization help to make firms more productive is fragmentary and anecdotal. Nonetheless, the fact that an increasing number of firms, from steel mills to agricultural chemical companies, are adopting these systems suggests that they are improving productivity either directly or indirectly. Another possibility is that some advanced technologies may be especially suited to work organization that stresses individual responsibility, flexibility, and multiple skills.

Methods of organizing work are changing in many cases to fully exploit new technologies. Many foreign and domestic firms are experimenting with the organization of work with goals of reducing costs, gaining flexibility to meet changing market conditions, exploring new products and services, and improving the quality of worklife. A new model of production systems seems to be emerging in the United States and in other advanced industrial nations. It is based on the idea of integrated production systems, with integration entailing substantial use of computers to tie together manufacturing operations, link manufacturing with design, and more closely couple both these activities with other corporate functions.[49] But

[49] See, for example, U.S. Congress, Office of Technology Assessment, *Computerized Manufacturing Automation: Employment, Education, and the Workplace* op. cit., ch. 3.

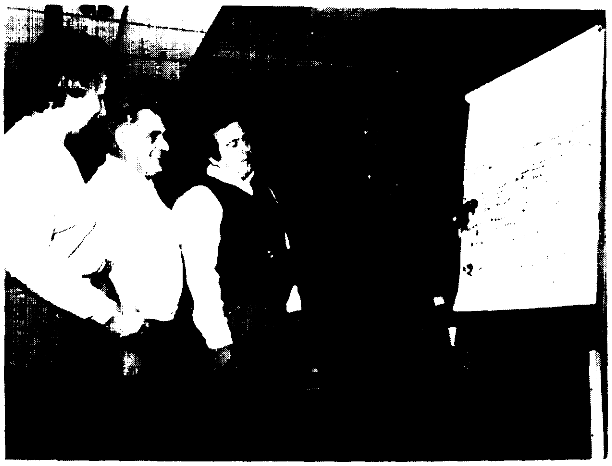


Photo credit LTV Steel Co

Employee involvement group

there is more to the idea of integration than technology. It includes the social system of the factory as well.

New-Model Organization of Work

Emerging forms of work organization in advanced industrial nations tend to share common characteristics, described below:

- *Production jobs are defined somewhat more broadly than in traditional organizations*. Work groups often share responsibility for a number of tasks, with individuals learning several jobs and rotating among them. Individual workers perform more tasks, and more varied tasks, and preassembly or subassembly may be integrated into final assembly. Production workers may also have greater responsibility for and control over materials handling, machine setup, maintenance and repair of equipment, quality control, and even production scheduling.
- *Companies tend to provide more training.* Even production workers normally classed as unskilled or semiskilled are getting more training. On-the-job training has generally proven adequate for many programs of job expansion or job rotation, broader skills coming with broader experience. Quality circles[50] and other group activities can also become training venues. Companies introducing work groups have sometimes chosen to provide training in social skills.

  Off-site training for production workers has been relatively rare in the United States, except for remedial education or training for jobs that incorporate tasks traditionally viewed as the province of skilled workers (e.g., troubleshooting production equipment).
- *Training is intended* in *part to acquaint employees with corporate goals and to enhance motivation, sense of belonging, and commitment to those goals.* Typically, companies show employees how their jobs contribute to the firm's end products. The employees are encouraged to view themselves as participating, for example, in the production of completed automobiles rather than merely in installing bumpers. ("I help build Honda Accords," rather than "I put bumpers on Hondas.") Some firms that have moved to new-model work organizations provide training that covers the function, design, and marketing of their products. Sometimes they include such topics as manufacturing methods, quality assurance, and ergonomics.[51] A few companies have begun to give employees "management information" on profitability y or long-range planning.
- *Management may allocate to groups of workers some or all of the responsibilities formerly vested in foremen and first-line supervisors.* . Workers may have limited control over the pace of work, job methods, and working conditions, and they may be responsible for quality control and for coordinating work within groups or departments. Such groups commonly allocate tasks among their members.

As the group takes over responsibility for controlling absenteeism, for ensuring quality, or for allocating work, the foreman's role may shift to that of facilitator and communication channel between the group and higher management. Often, the ratio of foremen to production workers declines. Many foremen with experience in traditional organizations have a hard time adapting to such changes, and careful selection or retraining of foremen often proves necessary. Some companies have chosen to eliminate foremen and first-line supervisors entirely.

Giving supervisory control to work groups can heighten the stress for some people. Among the causes are competition both within and among groups—the same forces that some managers look to for greater

[50] Quality circles usually consist of a group of workers meeting regularly to discuss product quality, process improvements, and related topics.

[51] Ergonomics and human factors engineering are closely related terms applied to the design of machinery and equipment so that it will be easy, safe, and efficient for people to use.

productivity. Work groups often have some control over their membership, perhaps veto power over new employees. Sometimes, new employees begin with probationary periods. People who do not fit in may find themselves not only uncomfortable, but out of a job. Thus, work groups have potential inequities and abuses that few companies have yet acknowledged.

- *Selection criteria for new employees may weigh motivational and attitudinal factors more heavily than credentials or past experience.* Social skills may also get new emphasis. Some American firms have adopted multiple levels of screening, with aptitude and perhaps psychological tests followed by interviewing. The interviews may involve prospective peers as well as supervisors and personnel officers. Rather than concentrating solely on preexisting skills, such screening procedures often aim at finding people who will fit into the system—at managerial levels as well as on the factory floor.
- *Pay scales tend to reflect the skills an employee has acquired (the jobs he or she has mastered), the performance of the work group, or both.* In addition to meeting objective standards such as written tests, a person seeking a pay-for-skills increment may have to be informally passed on by other group members, as well as by supervisors. Some companies are replacing individual incentive pay with group incentive plans, so called payment-for-results. Incentives or bonus plans may depend on product quality as well as output. Group-based incentives create new pressures on individuals. Where the spread in performance within a group is substantial, those viewed—rightly or wrongly—as laggards may find their situation untenable.
- *Managers may grant production workers a say in some of the decisions concerning new equipment and procedures, as well as day-to-day operations.* Typically, participation takes the form of group meetings among representatives of the production employees and the company's technical and managerial staff, When a new plant is laid out, the designers may draw on the experience of employees in the firm's existing factories. However, production workers have seldom exercised control over major design decisions–those that shape the system.
- *Companies may replace their existing, compartmentalized organization of work with one that is centered on the product.* People may identify more readily with a department that makes a complete product rather than a piece of one; thus product-centered organization helps engender employee motivation and commitment. Another goal of "product-centered organization" is to create a relatively direct and natural flow between the input and the output of the system. In many cases, organizing by product rather than by function also helps to minimize work-in-process inventories, cuts the elapsed time for producing to order, and improves equipment utilization.

Although no census exists, several hundred plants having characteristics described above are probably operating in the United States.[52] For example, General Motors (GM) is experimenting with alternative work organizations at some of its most automated plants, including the Buick City complex in Flint, Michigan, and the New United Motor Manufacturing, Inc., joint venture with Toyota in Fremont, California. Team assignments are replacing tightly defined job classifications, and production workers are assuming greater responsibility for scheduling and product quality. More far-reaching changes are planned for GM's Saturn project in Spring Hill, Tennessee. GM and the United Auto Workers have developed an approach that includes relaxed work rules, consensus decisions on pay and benefits, and a union voice in strategic planning. To prepare

[52] A few years ago, the Work in America Institute estimated that perhaps a hundred American firms had instituted self-managing work teams, in some cases at several plants. See *Productivity Through Work Innovations: A Work in America Institute Policy Study* (New York: Pergamon Press, 1982), p. 35, The same study estimated that about 500 U.S. companies had instituted bonus or gain-sharing programs such as Scanlon plans, Also see the *Resource Guide to Labor-A4anagement Cooperation* (Washington, DC: U.S. Department of Labor, October 1983].

workers for wider responsibilities, GM will provide training in production skills, decision-making, and business methods. For the Saturn project, GM has designed a totally new car, more suited than current designs to automated manufacture.

Service companies as well as factories can be organized in innovative ways. For example, some banks formerly centered around huge data-processing departments have switched to smaller departments specializing by type of customer (e.g., retailers) or type of transaction (e.g., currency exchange). When a single department provides most or all of the services a given client needs, the bank's employees tend to be more responsive, and the system becomes more intelligible to the customer.[53]

With the continued development of advanced production systems, the adoption of new-model organization of work may expand. Future generations of factories will be more highly automated, with distributed computing a primary tool for achieving greater integration. Although highly automated systems may need fewer employees, those employees will carry heavier responsibilities and need different skills than blue-, grey-, or white-collar employees in older factories. As pointed out earlier, automated systems cannot be idiot-proofed; indeed they tend to be more sensitive, less robust than labor-intensive systems, Thus, production workers may assume some responsibilities similar to those of supervisors and managers.

One implication of these changes is that employee control on the factory floor may gradually expand. At present, organized labor is often ambivalent about comprehensive redesign of factory systems, including elements such as quality circles. Unions have traditionally advocated detailed descriptions of jobs and strict demarcation between one job and another, and some labor leaders see these work rules as protective of jobs and pay. Others may believe that organizational redesign could provide more satisfying jobs, but are wary because job design and quality circles have been used as tools for keeping out unions. In general, labor has had little to say about reorganization of work around new technologies, although technical experts sometimes solicit the opinions and advice of shop floor workers, or committees representing blue-collar workers may be consulted. But with increasing responsibilities, operators of integrated, expensive, and sensitive technical systems may come to exercise more influence.

Another possible development is that barriers will come down within management. Product and production departments, with managers on the same level in the organization, will have to work together, much as production and quality control functions have already been integrated in new-model factories. Products will have to be designed for efficiency in manufacturing. This requires not only that product engineers work effectively with manufacturing engineers, but that technical staffs work effectively with production employees—learning from them during the design stage and helping them learn to produce the firm's goods or services efficiently and competitively.

Examples of New-Model Plants

A number of American and European countries have successfully adopted the model of work organization outlined above, and some of the same principles are at least implicit in Japanese companies. A Shell Canada chemical plant at Sarnia, Ontario, shows how the principles were applied in a technologically advanced continuous process manufacturing facility.[54] Shell Canada's highly efficient polypropylene and isopropyl alcohol plant started up in 1979 after 4 years of planning and a $200 million investment. The plant operates 24 hours a day, 7 days a week, with a staff of 210 people. All of its operators have been trained

[53] For an example, see R.W. Walters, "The Citibank Project: Improving Productivity Through Work Redesign," *The Innovative Organization: Productivity Programs in Action,* R. Zager and M.P. Resow (cd.) (New York: Pergamon Press, 1982), p. 109.

[54] Information provided by Joel Fadem, Institute of Industrial Relations, University of California, Los Angeles, under contract with OTA; L.E. Davis and C.S. Sullivan, "A Labour-Management Contract and Quality of Working Life," *Journal of Occupational Behaviour, vol.* 1, 1980, pp. 29-41; Norm Halpern, "Novel Organization Working at Shell Canada Facility, " *Oil and Gas Journal*, Mar. 25, 1985, pp. 88-93.

in equipment maintenance, quality control, scheduling, and safety as well as in process operations. (A team of journeyman craftsmen do the more complicated repair jobs.) Training in multiple skills, marked reduction of distinctions among workers, and a high degree of self-regulation are key features of the plant's operation. There are no job classifications for operators (termed shift team members), The pay structure rewards acquisition of new skills and allows all team members to reach the top rate.

The design team responsible for Shell Sarnia considered technical and human factors together from the start; representatives of the union (the Energy and Atomic Workers of Canada, formerly the Oil, Chemical, and Atomic Workers Union) were active participants. The team made important changes in the design originally proposed by the company's technical specialists, often in the direction of greater responsibility and control by operators. Studies of other highly automated chemical plants of the same type showed that the plants were often out of operation; the number of variables in the conversion process is very large, many causal relationships are poorly understood, and the final product may not conform to specifications, In a closed loop operation without human intervention, the process may have to be shut down while adjustments are made, At Sarnia, the computer system gives operators the information they need to fine-tune the chemical process and respond quickly to malfunctions, without having to shut down.

The Shell Sarnia system does not run on automatic pilot. To keep it working smoothly requires continuous training in technical and social skills. The results, from both the management and labor points of view, appear to be worth it. Quality control is reported to be excellent, throughput and on-stream time substantially above average, and absenteeism the lowest in any Shell Canada plant. In more than 6 years since the plant started up, only 11 formal grievances were filed—none after the first 3½ years, This compares with 150 grievances in the neighboring Shell refinery during the same period. The Sarnia experience has prompted Shell Canada to use a similar organization of work in several other facilities, including a new $1.4 billion oil refinery and styrene-monomer complex in Edmonton, Alberta.[55]

Rohm & Haas Bayport, Inc., a batch process plant near Houston that makes two lines of specialty chemical products, demonstrates a similar approach.[56] Startup operations at the Bayport plant began in 1982 with a line of specialty monomers. Production of an herbicide called Blazer began several months later.

Bayport employs about 110 people. Its production technology is conventional but its work organization differs markedly from that in other Rohm & Haas facilities, particularly the jobs of the 52 semiskilled production technicians—28 workers on one product line, 24 on the other. The plant manager, a veteran Rohm & Haas employee and the driving force behind the Bayport organization, stresses open communications and a nonbureaucratic management style. Organization of work at Bayport embodies the following elements:

- multiskilled technicians, each trained in five different jobs (most with no prior experience in the chemical industry);
- pay-for-skills through a ladder (as a technician masters each of the five jobs in turn, his or her pay rises);
- no use of shift foremen; and
- product-centered organization, with clear lines of responsibility.

Many of the work system features also extend to the secretarial and clerical staff. Technicians are carefully selected to fit the system. Rohm & Haas uses three levels of screening: 1) aptitude tests given by the Texas Employment Commission; 2) structured interviews carried out by Bayport managers; and 3) interviews by present technicians, The third level of screening was added after half of the first group of technicians left or were discharged

55 Halpern, op. cit., p. 93.

56 Based on OTA interviews conducted in February 1984, a telephone interview conducted in November 1985; and R.D. Gilbert, "What Do You Know About Participative Management?" *Chemical Engineering,* Apr. 1, 1985.

during plant startup. Current technicians now have veto power over new hiring and can also force the firing of someone who does not fit in. The plant manager chose most of the original management team himself; today, his immediate subordinates would screen new candidates for managerial openings just as the technicians screen their prospective peers.

performance evaluations are carried out every 6 months. Group meetings are part of the process, with peer ratings being a major factor in climbing the pay-for-skills ladder. If a technician fails an evaluation, he or she must devise a plan for passing within a specified time. The extensive screening of potential employees helped to keep worker turnover to 10 percent. While the technicians are all young (under 40), they are far from homogeneous, including both blacks and women.

So far, the new work organization seems to have been effective. All parties express a high level of satisfaction. The principal saving in direct costs has come from cutting out some of the supervisory labor of foremen. Extra costs have been associated with training technicians for multiple jobs.

Recently, the demand for Bayport's herbicide Blazer has dropped off, due to falling farm prices and incomes. Originally, the plant used contract workers to maintain equipment. To avoid laying off its own workers, Bayport has begun to train employees in maintenance, starting with a group of 12 workers and aiming to train 36 eventually. The full-time training course takes 4% months to complete, and is provided by staff engineers and the local community college; some of the instruction is by means of videotape. Once trained, the workers will add maintenance tasks to their duties.

Volvo's automobile assembly plant in Kalmar, Sweden, has become known around the world for its group-based assembly processes and unusual Iayout.[57] Much of the impetus for the plant design came from the problem of high rates of absenteeism and turnover which Volvo, in common with many Swedish companies, experienced in the late 1960s. When Volvo set out to design a new factory in the early 1970s, increased efficiency was not the primary goal; rather the objective was to improve employee satisfaction and motivation without directly sacrificing productivity. The company hired experts to interview 1,000 current employees. The survey results guided the architects and engineers, who also drew on the advice of two consultative groups, one that included technicians and foremen and another that included union representatives, safety officers, and specialists in occupational medicine and ergonomics.

The Kalmar factory is unlike other automobile assembly plants. It is light, spacious, and quiet, and its star-shaped form gives each work group a well-defined territory–including changing rooms, lounge, and sauna. The plant is small, with about 700 employees and a single shift capacity of 30,000 cars per year. Volvo management viewed small size as important for greater flexibility, as well as a better quality of working life through job enrichment and enlargement.

Both the plant layout and the group-based organization of assembly jobs create a sense of factories within a factory. The fundamental design decision was to replace the traditional moving assembly line with a system in which each car is assembled on its own carrier—essentially a self-propelled platform that follows magnetic strips in the floor. These carcarriers, designed by Volvo, tilt the entire car for work on the underside. A central computer monitors the positions of the carriers as they move from one workstation to the next. Start/stop signals for entering and leaving each station come from the computer but can be overridden by workers on the floor. A typical work area, manned by 15 to 20 workers, has several workstations and can accommodate six carriers at a time. Each car spends about 20 minutes in the group's work area.

While the plant's technical staff use conventional techniques to allocate tasks among work

[57]Information based on OTA staff visit to the Kalmar plant; also, see U.S. Congress, House Committee on Science and Technology, Subcommittee on Science, Research and Technology, *The* Human Factor in Innovation and Productivity (Washington, DC: U.S. Government Printing Office, 1981), pp. 182-252.

groups and stations, each group has a good deal of autonomy in carrying out their assigned tasks. Groups members typically rotate from job to job for variety, but few want to rotate from one group to another. One foreman supervises a pair of groups, while quality control inspectors function as members of the group.

Volvo is clearly satisfied with the results at Kalmar, The company claims that manhours per car are 25 percent less than at Volvo's other plants, and quality is high.[58] Capital costs were higher than at a more conventional assembly plant.[59] Absenteeism still runs around 24 percent: 10 percent "sickness," and the rest largely authorized; the sickness rate is reportedly half that at several other Volvo plants.[60] Surveys show that most Kalmar workers are satisfied with their jobs but also feel they have little chance to use all their skills or learn new ones.

National Policies Supporting Innovative Organization of Work

Sweden is one of the West European countries where governments have supported workplace innovation. Since the early 1970s, Sweden's system of official partnership between government, industry, and unions has encouraged changes in work organization and job content in connection with technological change. Largely a response to demands for more attractive jobs, the innovations include small, independent units of production and work roles that try to engage workers more fully. The Swedish Work Environment Fund, supported by industry levies plus government and private sector grants, provides money for research, development, training and education in work environment issues. In a 5-year program in the 1970s, the Fund spent an estimated $227 million on projects to improve occupational safety and health, broadly defined.[61] Recently, the Fund has shifted its emphasis toward improving the fit between computer-based technology and work organization. The Fund is currently supporting efforts which integrate technical and human concerns in designing advanced manufacturing and office systems.

West Germany has subsidized improvements in work organization to a greater extent than any other country. From 1974 to 1983, the West German government spent approximately $325 million on its Humanisation of Working Life Programme. Recently, spending has averaged about $50 million per year, against a backdrop of general fiscal austerity.[62] Over 1,500 projects have been completed and documented.

Results of the West German program have been mixed. It has emphasized engineering design as a major way of improving jobs, and has had some success in influencing factory design. Features such as modified assembly lines, buffers, and grouping of machines and work stations to improve the work environment have been adopted in many German companies. Human systems innovations, such as job rotation, job enlargement and enrichment, and semi-autonomous groups have been less accepted. The program's heavy reliance on behavioral science researchers, often lacking practical experience in industry, has sometimes led to conflict with managers, and with labor as well.

Until recently, these problems were aggravated by the West German goverment's policy of paying most of the costs of work humanization projects. As a result, host companies tended to view researchers as a necessary nuisance, and not to take their activities seriously. The policy has changed; companies must now pay half the cost of design research. Greater attention is being given to economic efficiency; work humanization is viewed as compatible with this aim. Small and medium-sized enterprises now also have greater access to program

[58] See S. Aguren, et al., *Volvo Kalmar Revisited: Ten Years of Experience* (Stockholm, Sweden: Efficiency and Participation Development Council, 1984), p. 12.

[59] Ibid., p. 28.

[60] P. Enstrom and K. Levinson, *Industrial Relations in the Swedish Auto industry—Developrnents in the Seventies* [Stockholm, Sweden: Swedish Center for Working Life, 1982), p. 36.

[61] The Swedish Work Environment Fund, *Programme of Activities and Budget, 1983/4-1985-86,* Summarised Edition, Stockholm, Sweden, pp. 10-11.

[62] David Jenkins, "Germany Engineers Work Humanization," *QWL Focus, vol. 3,* summer 1983, Ontario Quality of Worklife Centre, Toronto, Canada, pp. 23-25; and Peter Schuh, "Report From Germany, " Seminar Report of European Association of National Productivity Centres, in Work Research Unit, London, *Information System News and Abstracts No, 74* May/June 1985.

funds. In the United States there is no official government support of innovations in work organization, but interest in newer systems which include greater worker participation and responsibility appears to be rising. Production systems that better integrate people and machines hold the promise of cutting costs and improving products, especially with computer-based technologies. If the promise is fulfilled, participative work organization may become a strong factor in improving the competitiveness of U.S. industry.

APPENDIX 8A: FORECASTING THE EFFECTS OF TECHNOLOGICAL CHANGE ON JOBS

The effect of technological change on jobs raises concerns of various kinds among many people. Workers fear that their jobs will be eliminated, or altered to the point where they will need additional education or training to fill them. Managers worry that technological change will mean greater demands for particular kinds of workers than the Nation's schools produce, and educators worry that curricula will become obsolete. People choosing careers want to know what course of action will lead them to a good job; in some cases, changing technology can alter the picture in only a few years.

The Bureau of Labor Statistics (BLS) periodically makes and updates 15-year projections of employment by occupation and industry; these are widely used by labor market analysts and by job-training and high school counselors. The projections detail how many people are expected to be in the work force, and in what occupations and industries. Qualitative changes that occur within occupations—often as a result of applications of new technology—are not included in the projections.[63] BLS does attempt to incorporate the effects of technological change into its occupational/industry forecasts at several stages in the forecasting process.

Given the difficulties inherent in predicting technological innovation and diffusion, projections of the effects of technology on jobs, or even of the technologies themselves, have many uncertainties. For example, major innovations like the transistor and computers were not widely recognized as commercially important at first. Conversely, some innovations have failed to meet early commercial expectations; for instance, in the early days of television, many people forecast that television would revolutionize education, a promise which has not been fulfilled. The commercial viability and diffusion of process innovations are equally difficult to forecast. In 1964, an article in the *American Machinist* confidently hailed numerical control as "the one overwhelming metalworking development of the century, " and predicted that use of NC machines in the future probably would be limited "more by the capacity to build NC machines than by any other factor."[64] In the succeeding two decades, however, the diffusion rate was much slower than initially thought.

It is also difficult to judge the ways designers, managers, and workers will integrate new machines and technologies with people, since there is not one unique way to combine people and machines. Different organizations will approach the problem in different ways. Their decisions affect the number of people in different occupations as well as the skills and training needed in those occupations. For example, some clinical chemical laboratories, when buying machines to perform blood tests formerly done by hand, have chosen to keep college-

[63] BLS does evaluate qualitative changes expected in many different jobs in the ***Occupational Outlook Handbook,*** published every 2 years. The handbook describes the nature of different jobs, what training they may require, their pay scales, and the number of opportunities they may provide. The ***Dictionary of Occupational Titles***, compiled by the Employment and Training Administration (ETA), includes job descriptions for thousands of jobs based on on-site evaluation. While the dictionary contains a wealth of qualitative information, it is not designed to capture ongoing or potential changes in jobs.

[64] "The Impact of NC," *American Machinist, Oct. 26, 1964,* pp. NC2-4.

trained medical technologists in the lab jobs. The technologists are expected to be able to judge when a test result is suspect or may have life-threatening implications. Other laboratories have reduced the percentage of medical technologists and added less skilled medical technicians to run and monitor the machines, These labs retain some technologists to judge the validity of test results, but the number of positions for medical technologists is reduced.[65]

The study of occupations that are continually changing is also hampered by poor compatibility of data and changes in job classification systems. New job titles, for example, are frequently added to improve the detail of occupational data. Both historical figures and projections of the number of people in given occupations are available. Comparability suffers, however, as changes in the workplace alter occupational responsibilities, even if changes are not made in job classifications. Thus, identifying skill changes due to technology is at least a two-stage process: first, quantitative changes in occupational categories must be noted; and second, qualitative changes within each occupational category need to be evaluated,

Finally, the use of any technology—and therefore, its impact on jobs—depends heavily on a number of other factors which are difficult to forecast even for the immediate future. The list of these factors includes changes in consumer preferences and purchasing patterns, economic conditions, the objectives and strategy of labor and management, and the number and kind of competitors (domestic and international) in the field. In turn, many of these variables are themselves affected by technology; for example, access to the capital needed to invest in many up-to-date production technologies is a major determinant of what firms and nations can compete in the market. Isolating the effect of technology from these other factors is quite difficult, and adds to the uncertainties of forecasting.

[65]Bernard Ingster, consultant, persona] communication.

The Bureau of Labor Statistics Occupational Projections

For decades BLS has compiled and published data on present and future job prospects for people seeking employment in a range of occupations. This information, initially designed to be of service to veterans returning from World War II, is currently aimed primarily at high school guidance counselors and students who are making preliminary career decisions.

BLS must make assumptions about new technology in developing occupational projections; these assumptions are reflected in their resuits.eo Projections of occupations through 1995, for example, indicate that word-processing equipment will reduce the need for typists, and that the wider use of industrial robots will affect the demand for welders, production painters, and material-moving occupations. In the BLS predictions of the 20 fastest growing occupations, the effects of computers are clearly apparent for many—e.g., computer programmers, computer systems analysts, data processing equipment repairers. However, the 20 occupations where the largest job growth is expected in absolute numbers are largely traditional; for example, cashiers, registered nurses, janitors and cleaners, truck drivers, waiters, and salespeople, and nursing aides and attendants (see table 8A-1).

The BLS Employment Projection System is a series of five interconnected models that produce occupation-specific forecasts of employment for 378 industries and approximately 1,500 occupations.[67] These five models are:

1. labor force model—projects the size of the labor force based on demographic statistics and other considerations, such as increased participation of women in the work force;

[66]See U.S. Department of Labor, Bureau of Labor Statistics, "BLS Handbook of Methods, " Bulletin 2134-1, vol. 1, December 1982.

[67]John A. Hansen, "Bureau of Labor Statistics Methodology for Occupational Forecasts: Incorporating Technological Change, " contract report prepared for the Office of Technology Assessment, April 1984,

Table 8A-1.—Occupations With the Largest Job Growth and Fastest Growing Occupations as Projected by the Bureau of Labor Statistics, 1984-95 (numbers in thousands)

Occupation	Employment 1984	Employment 1995	Change in employment 1984-95 Number	Change in employment 1984-95 Percent	Percent of total job growth 1984-95
Largest job growth:					
Cashiers	*1,902*	*2,469*	***566***	29.8	3.6
Registered nurses	1,377	1,829	***452***	32.8	2.8
Janitors and cleaners, including maid and housekeeping cleaners	*2,940*	3,383	***443***	15.1	2.8
Truck drivers	*2,484*	2,911	***428***	17.2	2.7
Waiters and waitresses	*1,625*	2,049	***424***	26.1	2.7
Wholesale trade salesworkers	*1,248*	1,617	***369***	29.6	2.3
Nursing aides, orderlies, and attendants	*1,204*	1,552	***348***	28.9	2.2
Salespersons, retail	*2,732*	3,075	***343***	12.6	2.2
Accountants and auditors	*882*	1,189	***307***	34.8	1.9
Teachers, kindergarten and elementary	*1,381*	1,662	***281***	20.3	1.9
Secretaries	*2,797*	3,064	***268***	9.6	1.7
Computer programmers	*341*	586	***245***	71.7	1.5
General office clerks	*2,398*	2,629	***231***	9.6	1.4
Food preparation workers, excluding fast food	*987*	1,205	***219***	22.1	1.4
Food preparation and service workers, fast food	1,201	1,417	***215***	17.9	1.4
Computer systems analysts, electronic data processing	308	520	***212***	68.7	1.3
Electrical and electronics engineers	390	597	***206***	52.8	1.3
Electrical and electronics technicians and technologists ... ,	404	607	***202***	50.0	1.3
Guards	733	921	188	25.6	1.2
Automotive and motorcycle mechanics	922	1,107	185	20.1	1.2
Fastest growing occupations:					
Paralegal personnel	53	104	51	97.5	0.3
Computer programmers	341	586	245	71.7	1,5
Computer systems analysts, electronic data processing (EDP)	308	520	212	68.7	1.3
Medical assistants	128	207	79	62.0	0.5
Data processing equipment repairers	50	78	28	56.2	0.2
Electrical and electronics engineers	390	597	206	52.8	1.3
Electrical and electronics technicians and technologists	404	607	202	50.7	1.3
Computer operators, except peripheral equipment	241	353	111	46.1	0.7
Peripheral EDP equipment operators	70	102	**32**	45.0	0.2
Travel agents	72	103	32	43.9	0.2
Physical therapists	58	83	25	42.2	0.2
Physician assistants	25	35	10	40.3	0.1
Securities and financial services salesworkers	81	113	32	39.1	0.2
Mechanical engineering technicians and technologists	55	75	20	36.6	0.1
Lawyers	490	665	174	35.5	1,1
Correction officers and jailers	130	175	45	34.9	0.3
Accountants and auditors	882	1,189	307	34.8	1.9
Mechanical engineers	237	317	81	34.0	0.5
Registered nurses	1,377	1,829	452	32.8	2.8
Employment interviewers, private or public employment service	72	95	23	31.7	0.1

SOURCE: George T. Silvestri and John M. Lukasiewicz, "Occupational Employment Projections The 198495 Outlook,<' *Monthly* Labor Review, VOI 108, No. 11, November 1985, pp. 51-52.

2. macroeconomic model—predicts the future level of economic activity based on assumptions concerning growth in the gross national product, defense spending, inflation rate, and other factors;
3. industry activity model—projects the aggregate demand for goods and services for each industry;
4. industry labor demand model—projects the total labor requirements by industry; and
5. occupational labor demand model—provides a breakdown of labor demand in each industry by occupation.

The fifth model, providing occupational projections, incorporates the results and assumptions of the other four models. If results from any of the models are inconsistent with initial assumptions, other model adjustments or new assumptions are made. These changes are based on judgments and may affect other model results. BLS therefore repeats the procedure until all conditions are met. If, for example, the projected number of aircraft assemblers is assumed to be reduced due to technological change, the growth rate of this occupation can be reduced in the model. To meet a predetermined staffing ratio other occupations in the same industry would be adjusted upward. Several of these adding-up requirements may have to be made with respect to a single technological assumption.[68]

Virtually all the effects of technological change encompassed in the modeling system are introduced through exogenous adjustments made by BLS staff. The staff is aware of the importance of technological change and does make changes in the models to accommodate them. The BLS staff is conservative about making adjustments to the model based on technological change; unless there is both evidence that an adjustment is required and evidence about the appropriate magnitude of that adjustment, BLS assumes that the future will follow historical patterns,[69] However, even with this conservatism, hundreds of adjustments are made. BLS analysts make the adjustments on the basis of officewide guidelines about the basic economic assumptions that underlie the model, and on the strength of their own knowledge of particular industrial sectors. Often, the changes made to incorporate the effects of technological change represent the judgments of one or a few analysts. This is not necessarily inappropriate; regardless of the forecasting procedure involved, forecasts must represent the judgments of individuals about the future, if they are not to be a simple extension of past trends. However, because it is difficult to make accurate judgments about many future possibilities, the most useful forecasts incorporate sensitivity analyses to show how the outcome of the forecast depends on the assumptions used in making the forecast.

Despite the uncertainty about the kinds and rates of technological change, BLS has performed no sensitivity analyses on the model with respect to different technological futures. With budgetary considerations forcing BLS to reduce the number of occupations reviewed, it is unrealistic to expect a more formal evaluation of technologies in the near future. BLS sensitivity analyses are mainly confined to varying macroeconomic assumptions—e.g., GNP growth, personal consumption, imports and exports, government expenditure, the growth of the labor force, and worker productivity–to produce estimates of employment in high, moderate, and low ranges. This sensitivity analysis is useful but limited. As a result, the 15-year forecasts tend to become outdated in only a few years, For example, forecasts published in June of 1979 expected exports to grow more rapidly than imports through the 1980s, while in fact the first half of the decade has been marked by record American trade deficits. The same projection expected manufacturing employment to increase to over 23 million in 1985; in fact, manufacturing employment in 1985 was about 19,4 million—1.6 million below the actual 1979 level, and 3.6 million below the projected figure.[70] BLS updates its long-term

[68] Hansen, op. cit.
eel bid.

[70] Valerie A. Personick, "Industry Output and Employment: BLS Projections to 1990, " *Monthly Labor Review*, April 1979, pp. 25-36.

forecasts every 2 years, correcting for the difference between the projected and the actual; even so, long-term forecasts, without a great deal more sensitivity analysis, are not reliable indicators of what will happen.

The *Dictionary of Occupational Titles*

Many analysts, when looking at qualitative aspects of jobs, rely on another publication of the Department of Labor, the *Dictionary of Occupational Titles (DOT),* published since 1939.[71] The *DOT* attempts to identify the skill and training requirements of a very large sample of jobs in the economy. *DOT* categorizes titles and descriptions of 12,099 occupations. According to the most recent (1977) edition, *DOT* is intended for use in employment counseling, in career guidance, and in developing public and private labor plans and training programs,

In analyzing the skill requirements for each job, *DOT* first breaks the job down into worker functions associated with people, data, and things, and then ranks the job within these categories. For example, in jobs that involve handling data, the highest level is "synthesizing," the lowest level "comparing." Second, job titles are categorized according to traits on computer tapes available to users of *DOT*. These traits include education and training requirements, aptitudes, temperaments, interests, physical demands, and working conditions. In characterizing thousands of jobs by function and trait, *DOT* acts as a large job evaluation system for the entire U.S. economy. The criteria used in ranking jobs are subjective, but that is a weakness common to most job evaluation systems. However, the *DOT* has some particular limitations of its own.

Specifically, *DOT's* job analysis methods are most suited to jobs that can be broken down into discrete tasks, particularly manufacturing jobs. The factors and scales used in rating worker functions and traits were developed in the 1950s using a sample of occupations, mainly those in manufacturing. Since then, employment growth in the service sector has outpaced growth in manufacturing jobs, and new technologies have entered the workplace. These changes have undercut the validity of some of the *DOT* skill measures. Additionally, some *DOT* job descriptions may be weak because of poor management of the onsite analyses used in compiling the 1977 edition.[72] In addition, the document's coverage of newly emerging industries and occupations may be inadequate, because the 1965 edition of *DOT* was used as the sampling frame for jobs included in the 1977 edition.[73]

Despite its limitations, *DOT* is extensively used. Job placement interviewers within the State-Federal Employment Service rely on the job titles and definitions to match unemployed workers with openings in State and local job banks, and Employment Service counselors use the information on workers' traits to help clients explore vocational options. *DOT* is also used by counselors, personnel managers, employment placement officers, and labor market analysts in schools, government agencies, and private firms.[74] The Bureau of Apprenticeship and Training uses it for training, the Veterans Administration relies on it for rehabilitation and employment counseling, and vocational educators use it for counseling and curriculum development. In 1980, following an extensive study of the 1977 edition, the National Academy of Sciences concluded that there was a strong and continuing need for the kind of information that *DOT* provides.[75]

DOT was not designed to depict the influence of technological change, although some information can be gleaned from individual job descriptions, As an illustration, box 8C gives the job descriptions for an injection machine operator and an injection machine tender for the manufacture of plastic products. One of the most noted occupational changes with automatic production equipment is the shift from

[71] U.S. Department of Labor, *Dictionary of Occupational Titles*, 4th ed. (Washington, DC: U.S. Government Printing Office, 1977).

[72] Ann R, Miller, et al., Work, *Jobs*, and *Occupations: A Critical Review of the Dictionary of Occupational Titles* (Washington, DC: National Academy Press, 1980), p. 146.

[73] Ibid.

[74] Ibid., p. 91.

[75] 1 bid., p. 214.

Box 8C.—Sample Occupations From the *Dictionary of Occupational* Titles

656.382-014
Injection-Molding-Machine Operator (fabric. plastics prod.) injection molder; molder.

Sets up and operates injection-molding machines to cast products from thermoplastic materials: Installs dies on machine, according to work order specifications, using clamps, bolts, and handtools. Sets machine controls, regulating molding temperature, volume of plastic molding pressure and time, according to knowledge of plastics and molding procedures. Dumps premixed plastic powders or pellets into hopper, and starts machine. Pulls lever to close dies and inject plastic into dies to cast part. Removes finished product from dies, using handtools. Trims excess material from part, using knife. May mix thermoplastic materials and coloring pigments in mixing machine, according to formula. May grind scrap plastic into powder for reuse.

556.685-038
Injection-Molding-Machine Tender (fabric. plastics prod.; phonograph; rubber goods)

Tends injection-molding machines that form plastic-or rubber products, such as typewriter keys, phonograph records, and luggage handles: Dumps plastic powder, preformed plastic pellets, or preformed rubber slugs into hopper of molding machine. Starts machine that automatically liquefies pellets, slugs, or powder in heating chamber, injects liquefied material into mold, and ejects molded product. Observes gages to insure specified molding temperature and pressure are maintained. Examines molded product for surface defects, such as dents and cracks. May heat plastic material over steamtable or in oven to prepare material for molding. May remove product from mold, using handtools. May trim flash from product, using shears or knife, May place product in cold water or position it on cooling fixture to prevent distortion.

Source: U.S. Department of Labor, Employment and Training Administration, *Dictionary of Occupational Titles*, 4th *ad.* (Washington, DC: U.S. Government Printing Office, 1977), pp. 407, 409.

controlling to monitoring work tasks. The two job descriptions demonstrate this shift. Yet the descriptions do not explicitly reveal that the machine tender's job is in a more technologically advanced system than the machine operators. The equipment for each job is not described, and various ways in which tasks are allocated within these jobs is not apparent,

DOT job descriptions could be made clearer if closer attention were given to occupational comparisons and changes within job titles. Data from additional onsite evaluations and survey data could help in updating the DOT, to make it better reflect the nature of existing jobs. Up-to-date descriptions would help workers in making job transitions, by providing information that would allow matching a worker's past experience with the requirements of current jobs.