Chapter 4

Effects of Programmable Automation on Employment

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Chapter 4

Effects of Programmable Automation on Employment

Summary

Employment change due to programmable automation (PA) will not be precipitous. Programmable automation will depress the number of jobs available in manufacturing, but it will not necessarily cause significant national unemployment during this decade or even the next. By eliminating specific tasks and by contributing to major changes in manufacturing processes and organizations, PA will "displace" jobs (where jobs are defined as sets of tasks performed by individuals working a standard number of hours). Whether unemployment occurs depends not only on these displacement effects, but also on the level of production volume (which depends on foreign trade and consumer demand), and on the numbers and types of people seeking work.

Slower growth in the labor force, increases in capital goods production, and limited or imperfect use of PA technology are among the factors likely to buoy manufacturing employment during this century. However, regional and local employment may suffer due to the combined effects of labor-saving technology, import competition, and other factors, especially where area economies depend on so-called declining or mature industries. Yet PA may help firms in those industries employ more people than they might otherwise—at least to the extent that it makes them more competitive. Cumulative experience and improvements in technical capabilities and costs should increase the use of PA (and its employment effects) during the 1990's relative to the 1980's.

Programmable automation will reinforce the ongoing trend toward increased "white collar" or salaried employment and increased service industry employment, although skill requirements for jobs at all but the highest levels in manufacturing may fall. Producers of PA are particularly likely to employ predominantly salaried personnel, especially if they continue to import significant amounts of PA hardware from overseas. Consequently, there will be few opportunities for people to move directly from production jobs where PA is used to jobs producing PA. Also, the limited amount of actual production work expected among PA industries is one reason OTA expects that job creation among producers of PA equipment and systems will be less than job loss among users.

Programmable automation will blur distinctions between occupational categories and present vast opportunities for restructuring jobs. Among occupational groups, technicians will become more prominent with the spread of PA, in part because they will perform tasks otherwise performed by engineers or skilled tradesmen. Engineers will nevertheless constitute a growing share of manufacturing employment, as may mechanics, repairers, and installers. Operatives, laborers, and production-clerical personnel are the most vulnerable to displacement.

PA will provide new opportunities for structuring jobs because of its tendency to displace and to create individual tasks. It therefore raises questions about the tradeoff between large numbers of narrowly defined jobs–customary in manufacturing to date-and smaller numbers of more broadly defined jobs. How and whether the potential for positive change in job design and the organization of work is realized depends on decisions by individual managers. Many factors—e.g., the operating speed of automated equipment, the breadth of functions it can perform, and the reduction in average skill requirements some users may experience–may cause a problem of overconfidence in programmable automation. There is a risk that users may too readily assume that the computer knows best, overlooking the value of experience-based understanding of manufacturing processes.

Introduction

The elimination of jobs will be a principal long-term effect of programmable automation: PA technologies are designed to reduce labor hours in production. They are sold as labor substitutes, whether or not the total number of employees will actually fall with their use. Even the advertising language emphasizes the capacity of machines to emulate or improve on human performance (e.g., "the graphics lathe control that thinks like a machinist"). In addition to its impacts on the number of jobs, programmable automation will also bring about major changes in job content and job mix in the manufacturing workplace. All of these effects will occur not because of technological change alone, but because of concomitant changes in how companies are organized and managed and in what and how much they produce.

This report does not examine employment change exhaustively. * Doing so would require a thoroughgoing examination of changes in the structure of the economy and individual industries. The report does, however, show how one set of technologies (which can be used across an unusually broad range of industries) may alter demand for labor. It shows that programmable automation creates enormous potential for change in the use of labor. Not only will it reduce the amount of labor used to produce a given amount of product, it will also motivate shifts in the mix of personnel and in the services sought from employees. PA will directly or indirectly affect all types of personnel, professional and technical as well as production and clerical.

*For additional treatment of employment change, see upcoming OTA assessments on technology and structural unemployment; technology, innovation, and regional economic development; and economic transition.

Despite this broad potential for change, no one set of impacts is inexorable. PA and other factors (e.g., changes in consumer demand and in the business relationships between firms) will present employers with choices about the number and types of personnel they use. The outcomes of those choices will determine future staffing patterns and employment levels in firms and industries.

Prior to examining the employment effects of programmable automation, it is useful to review some basic labor market characteristics and analytical concepts. In the aggregate, changes in industry or national employment levels depend principally on economic conditions, including both short-term cyclical conditions and more profound structural changes in the economy. These conditions reflect changing buying patterns of consumers as well as the investment decisions of companies and Federal budget policy (which affects the financial resources of individuals and businesses). The numbers and types of jobs depend heavily on the numbers and types of goods and services consumers demand and on the countries from which they buy them. For this reason, import (and export) levels—which reflect preferences for foreign products relative to domestic ones—are an important determinant of employment.

Technology used in production is a secondary influence that is dwarfed by the effects of demand changes; it governs the mix of labor and other inputs. Technology change generally affects employment much more slowly than do demand shifts, because it does not affect an industry or an economy all at once. Automation, in particular, is typically adopted during periods of economic expansion, a timing that facilitates the adjustment of work forces through attrition.*

While it is hard to attribute past employment growth to a single technology change, the introduction of new products and production processes has historically been associated with employment growth. This has occurred despite the fact that productivity improvement (due to technology or other factors) by itself—i.e., unaccompanied by change in production volume or in the average number of working hours per job—will result in fewer jobs.**

The fact that interest in automation has grown during two closely spaced recessions tends to confuse the perceived relationships between automation and employment. Many employers laid off personnel because of the recessions, as is usual; what is unusual is that some may not rehire to pre-recession levels because of recent or planned automation, and/or because of permanent declines in their business. Thus, the percentage of unemployment due to permanent separations (as opposed to layoffs and other factors) grew during the last recession. These developments will likely slow the return of the unemployment rate to pre-recession levels.[1] On the other hand, because of the recessions and recent high interest rates many firms avoided investing in new equipment. The recovery may outpace their ability to automate, or it may fail to generate sufficient profits for them to automate.

The auto industry exemplifies all of these possibilities to some degree. Yet it was widely recognized before the recent explosion of interest in robots that U.S. automobile manufacturers were unlikely to hire to prior peak levels anyway, at least during the 1980's, because of changes in the auto market, such as growth in imports.[2] In some industries, such as autos, PA may help to preserve jobs by helping domestic firms repel import competition, although total industry employment may fall.*

Changes in employment levels will depend not only on how technology and economic conditions affect industries immediately involved in producing and using the technology; they will also depend on how related industries (e.g., suppliers and customers) are affected. Evaluation of both direct and indirect employment effects generally requires a macroeconomic model that captures interindustry links and their sensitivity to changes in prices and tech-

*These points are frequently raised by the Bureau of Labor Statistics. Also, West German research shows that on an overall industry level, the timing of adoption of automation, relative to when it is first introduced, affects the rate and level of employment change. A West German study found that the actual and hypothetical employment reductions associated with numerically controlled (NC) machine tools fell between 1973 and 1979; actual layoffs were negligible. The authors concluded that the potential for displacement depended on where the technology was used: compared to the early ones, later NC investments were aimed at replacing old equipment rather than expanding capacity, and such installations were more common among relatively small users, where the opportunity for productivity improvement (and displacement) was lower.

As that study illustrates, estimates of potential displacement should allow for change in baseline conditions over time. Another German study estimated that, when used as an alternative to stand-alone NC, newer flexible manufacturing system (FMS) technology could displace 1,000 to 3,000 people by 1990, or less than 1 percent of metalworking employment. The authors concluded that organizational inertia and difficulties involved in using the relatively new technology would retard actual displacement. The conclusions drawn in these studies are consistent with the expectations of analysts who are familiar with American use of NC and FMS. See Werner Dostal, et al., "Flexible Manufacturing Systems and Job Structures" (Mitteilungen aus der Arbeitsmarkt- und Berufsforschung), 1982; and Werner Dostal and Klaus Kostner, "Changes in Employment With the Use of Numerically Controlled Machine Tools" (Mitteilungen aus der Arbeitsmarkt- und Berufsforschung), 1982.

**OECD, for example, has estimated that if productivity were to rise 10 percent between 1980 and 1990 and world trade failed to grow over the decade, aggregate employment would be O to 4 percent lower than in 1980. However, OECD believes that the higher estimate is unrealistic, because such productivity growth would be unusually high, permanent increases in productivity growth rates are unlikely, and static trade is especially unlikely. *Microelectronics, Robotics and Jobs*, OECD, Paris, 1982, p. 90.

[1] Robert W. Bednarzik, "Layoffs and Permanent Jobs Losses: Workers' Traits and Cyclical Patterns, *Monthly Labor Review*, September 1983.

[2] See *Increased Automobile Fuel Efficiency and Synthetic Fuels: Alternatives for Reducing Oil Imports* (Washington, D. C.: U.S. Congress, Office of Technology Assessment, OTA-E-185, September 1982).

*For reference, note that Arthur D. Little concluded from a study of West European auto manufacturing that, despite an anticipated $40 billion investment in programmable automation during the 1980's, the West European share of the world auto market will continue to fall, and its employment capacity may fall by as much as 30 percent from current levels. See Martyn Chase, "European Car Makers Seen Installing $40 Billion in Automation Equipment, " *American Metal Market/Metalworking News*, Feb. 28, 1983.

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nologies. At this time, available data are not adequate to fully model the likely impacts of PA.

A major advance in this direction comes from a study recently conducted at New York University. It concluded from an input-output analysis that, given the likely impacts of several computer-based technologies on labor requirements in manufacturing, education, health, and the office workplace, and given the employment generated by increased production of computerized equipment, significant unemployment during this century is not likely to result from progressive computerization (provided that the work force can satisfy shifting occupational and sectoral requirements).

That study illustrates how employment in manufacturing can be stimulated through this century by the production requirements of potential rates of installation of computers and automation into the manufacturing and office environments. The study underscores the important role that domestic production of capital goods—demand by businesses for the products of other businesses—plays in maintaining domestic employment levels. It also shows that slower growth in the labor force can blunt the employment effects of labor-saving technologies. As the authors note, additional work is needed to assess the effects of other factors on employment, such as possible changes in production materials, in level and manner of equipment integration, and in trade patterns.[3]

OTA shares the view that use of programmable automation can grow, as is expected, without large increases in national unemployment during this century. The effects on employment of labor-saving technologies can be offset in the aggregate by changes in the labor force, as well as by likely increases in output for capital goods and other products. Such output growth, of course, assumes a strong economy. However, the transition in industry structure and occupational profiles accompanying PA and recent growth in imports may burden individuals and communities at least temporarily, especially if PA use grows more quickly and extensively than appears likely during this decade. Changes in industry demand for specific skills will make it harder for some individuals to find or change jobs, as will regional dependence on specific industries. Thus, PA may aggravate ongoing local unemployment. While the Nation as a whole will benefit from the productivity gains expected from PA, it will not benefit fully if otherwise productive labor resources are idled for long periods of time.

Analysis of the employment impacts of programmable automation is fraught with difficulty. Briefly, analysts generally approach the problem from two perspectives: the engineering approach, which focuses on the potential for equipment to substitute for people on a task-by-task basis; and the economic approach, which derives employment estimates from models of the interaction among industries based on their requirements for labor and other production inputs. Both approaches have shortcomings.[4] Moreover, the number of different PA technologies, the range of equipment designs and implementation strategies, and uncertainties about the speed and success of technical advances make the formulation of general rules about job loss (or creation) risky. So, too, does existing variation among employers (even in the same industry) in job mix, job definition, and adaptability to change. Finally, data describing prevailing skill requirements, jobs, and job mixes among firms are limited. As the technical memorandum published during the course of this assessment explained, predictions of employment impacts should be regarded with caution. Available data only permit insights into the likely directions for employment change.

This chapter examines how PA is likely to affect employment opportunities, drawing on inferences from case studies, site visits, interviews, and technical literature. It focuses on change at the level of the firm and the indus-

[3] Wassily Leontief and Faye Duchin, *The Impacts of Automation on Employment, 1963-2000,* final report, New York University, Institute for Economic Analysis, April 1984.

[4] Ibid.

try. The first section describes how, and why, programmable automation will shape job opportunities. It traces potential effects on tasks and skills. The second section describes where employment impacts are likely to be experienced, by industry and by geographic region. The third section explores the implications of programmable automation for specific occupational groups. Together, the first three sections identify the groups of people most likely to experience employment change and the types of change they may confront.

The final sections address the implications of those changes for the labor market overall. The fourth section discusses the overall effect of likely impacts on tasks, skills, and occupations. It draws on other studies of individual automation technologies and industries to provide perspective. The fifth section discusses contextual factors that will shape observed employment patterns. It identifies trends in the supply of labor, and it describes recent Japanese experiences in adjusting to automation.

Effects of Programmable Automation on Jobs

As figure 14 illustrates, change in employment induced by new technology depends on how technology alters the tasks to be done in manufacturing jobs, on what changes occur in the skills required for different tasks and jobs, and on how the roles of different occupations change; total employment change also depends on changes in how labor is used within and between industries and changes in labor supply. The effects of PA on work opportunities are so varied and (at times) so profound that they call into question the basic definition of "skill," the identification of where skill fits into the production process, and the relationships between tasks, skills, occupations, and jobs. Changes in task assignments and skill requirements vitiate traditional occupational descriptions, which form the basis of occupational employment forecasting. *

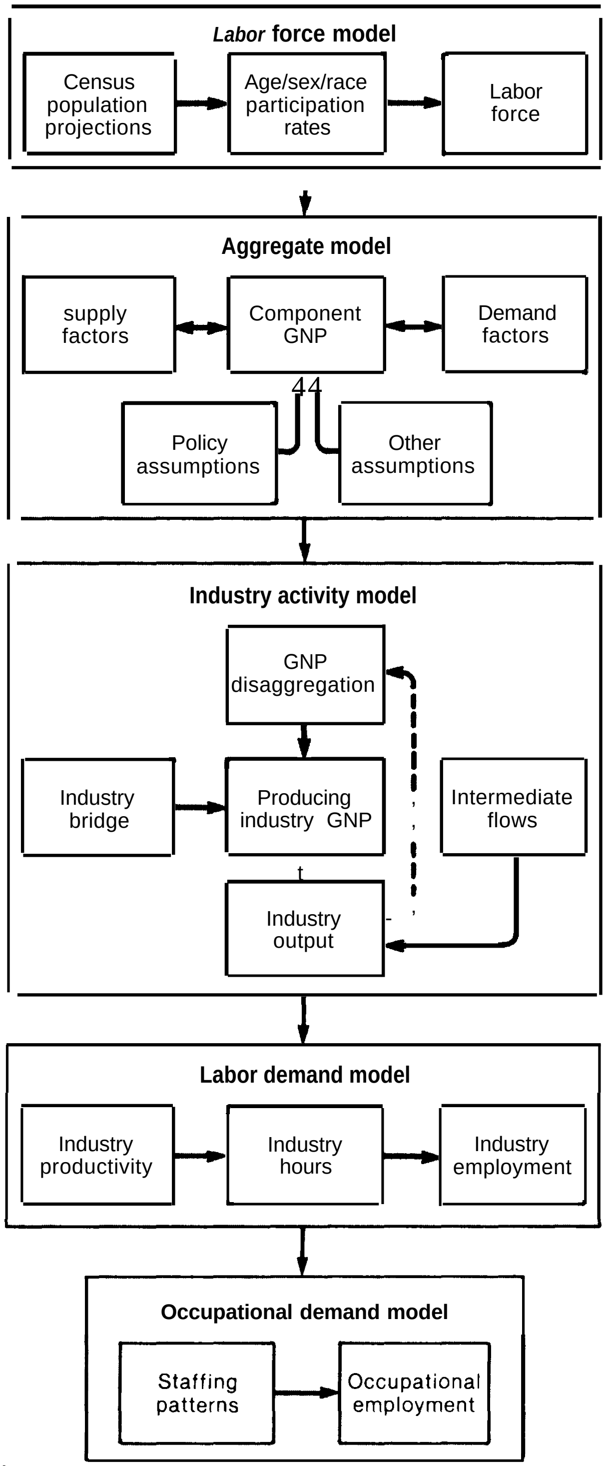
Employers create jobs by combining sets of tasks and allocating them to individuals. Jobs with similar descriptions and avenues of preparation are classified as occupations. Indeed, the design of training programs depends on the expectation that people in designated occupations or jobs will perform specific tasks. Unfortunately for the analyst, what is actually done on the job frequently differs from the formal job description. Differences in actual function between various jobs and occupations are often nominal, while companies differ in what they ask of people in the same occupations, even within a given industry.

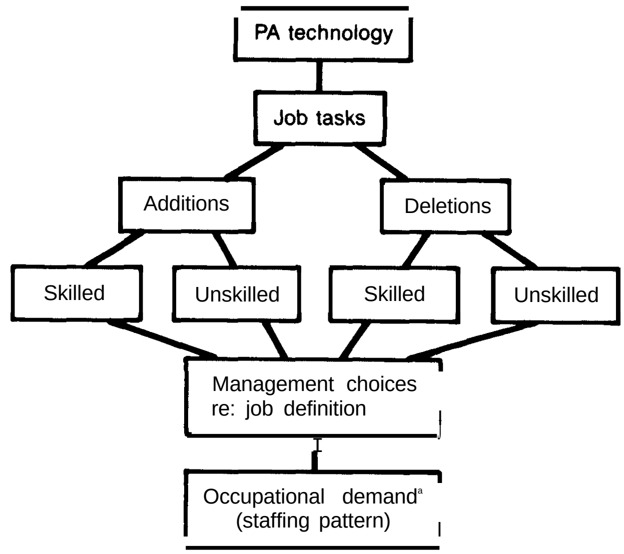
Computer-based technologies, including numerical control (NC) technology, have already led to different staffing patterns within and among countries, varying on the basis of industrial traditions, labor market conditions, prevailing types of company structure, and national educational systems. These variations further complicate employment forecasting, as employment change depends on a series of decisions yet to be made by current and potential employees, employers, and educators.

A German analysis of flexible manufacturing systems (FMS), for example, concluded that work within an FMS was comprised of a set of tasks that could be allocated in numerous ways generally not bound by the technology (see table 16). The authors illustrated this point by contrasting two cases, one with three types of jobs directly associated with the FMS, the other with five. They concluded that, while the technology permits unusual freedom in defining jobs, and is particularly conducive to multifaceted jobs, radical change in job de-

*The changes may occur only informally, at least at first, and may not be reflected in job titles.

Figure 14.—Conceptual Model: Occupational Demand Change





[a]Employment levels will depend on industry and labor supply factors, as well as levels of economic activity, as noted in larger model above

SOURCE" Of fice of Technology Assessment, with input from Robert Bednarzik of the U S Department of Labor; Bureau of Labor Statistics

scriptions is a distant prospect due to the slowness of organizational change.[5] OTA shares this perception.

Effects of Programmable Automation on Tasks

Although each application of programmable automation in the workplace is unique, OTA's analysis reveals some common trends in how automation affects the use of labor. At the simplest level, automation displaces and/or creates tasks: Where tasks are transferred from people to machines, fewer jobs are associated with the production of a given amount of product. This transfer process constitutes displacement-the elimination of tasks (and ultimately of jobs) that would have been available but for automation. On the other hand, the introduction of new equipment and systems into the workplace also creates tasks, particularly in the design of products and the maintenance of the equipment. The situation becomes more complex where production processes change more significantly. In this case, even tasks and personnel associated remotely, or not at all, with the primary tasks performed by the equipment will be affected.

'Werner Dostal, et al., "Flexible Manufacturing Systems and Job Structures" (Mitteilungen aus der Arbeitsmarkt- und Berufsforschung), 1982.

Table 16.—Basic Tasks: Activity Elements With NC Machines and Flexible Manufacturing Systems

Programing and planning:
1. preparation of a program
2. modification of a program
3. preparation of tool blueprint
4. preparation of mounting blueprint
5. processing problems: interviews for additional information
6. the activities of a programer or operator in case of breakdowns

Preparation and equipment:
1. making the tools available and transportation of tools and mounting means
2. presetting of tools and mounting means
3. control of tool installation; bringing of tools into play
4. preparation and setting up of mounting means and devices
5. lifting and putting down of a workpiece
6. mounting of workplaces according to the mounting blueprint and one's experience
7. control of mounted workplaces
8. switching on and adjustment of refrigerant afflux

Preparing and equipping:
1. input output media insertion, spooling removal
2. zero adjustment
3. placing the correction switch according to tool and mounting blueprint
4. placing correction switch towards tool lock
5. test run with coordinate and cutting direction control

Operation and supervision of machines:
1. starting of a program run
2. observing of the operating cycle
3. removal of shavings
4. changing of tools and mounting
5. supervision of the operating status of the installation
6. discovery of false control movements
7. activating of the switch in case of breakdowns
8. removal of breakdowns

Controlling and monitoring:
1. measure and surface control during processing
2. control of the complete workplaces
3. installation care
4. putting into operation and keeping in operation
5. training of an operator

SOURCE W Dostal, et al, "Flexible Manufacturing Systems and Job Structures" (Mitteilungen aus der Arbeitsmarkt- und Berufsforschung), 1982

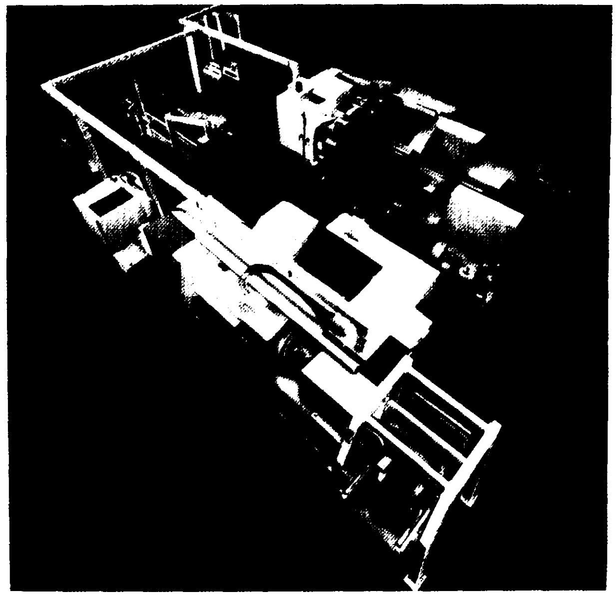


Photo credit Cincinati Milacron, Inc

Machine cell with two computerized numerically controlled turning centers and robot for machine loading/unloading and inspection

Task Displacement

Automated equipment and systems perform specific, primary tasks previously or otherwise done by people, such as welding, materials handling, and revision of product designs. The fewer the tasks in the original job definition, the more likely that automation of a given task will lead to job displacement. For example, if a person does only spot welding, the introduction of a spot-welding robot is more likely to result in the elimination of part or all of that job than if the person did spot welding and other tasks, such as welding-gun repair.

Programmable equipment and systems can substitute for labor more readily than can conventional equipment, in part because of their versatility; a single system can perform multiple tasks. In particular, they perform secondary tasks in the factory, such as collecting and transferring information on equipment use or movement of parts, and even automating the flow of materials. Consequently, programmable automation may assume tasks traditionally done by nonproduction labor, from managers to stock-chasers, as well as those done by production workers. Also, substitution for labor may occur when PA is used to replace other types of equipment. For example, robots have been adopted by automobile manufacturers as an alternative to automatic welding machines (run by people) to do spot welding in automotive assembly.

The possibilities for displacing labor are generally greater for computer-integrated manufacturing (CIM) systems than for stand-alone applications of automation, although such systems do not eliminate all need for human input. For example, a single arc-welding robot may require an operator (although that robot/person combination may make the hiring of additional welders unnecessary if it is more productive than a single human welder). On the other hand, a single materials-handling robot serving other pieces of equipment may displace a human materials-handler without requiring an operator, although at least one person may oversee the larger assemblage of equipment. Similarly, flexible manufacturing systems have the potential to displace more people for a given set of machining tasks than do stand-alone NC machine tools. However, because the art of designing and implementing successful integrated manufacturing systems remains immature, and because FMS implementation is (and is expected to remain) limited, significant labor displacement by either CIM or FMS is unlikely in the near term.*

Programmable automation does not always substitute for labor in an obvious or direct way. For example, early research into bin-picking robot applications showed that it was more efficient to do away with human-like sequences of steps than to imitate them.[6] In some cases, automation accompanies or motivates major changes in production processes which themselves alter the use of labor. As a sequence of production operations, a process determines the types and amount of tasks humans or machines can perform. For example, computer-aided design (CAD) (in its higher forms) allows many product designs and production plans to be tested through simulations rather than through the building and manipulation of prototypes. Accordingly, an aircraft manufacturer developed a CAD package for rationalizing piping design, replacing its prior practice of building full-scale mockups of pipe layouts against which production piping was then matched.[7] These two practices, prototype and simulation, have vastly different implications for staffing: in simple terms, prototype construction involved production labor, especially skilled workers, while simulation and computer analysis involve engineers and technicians.

Other cases of process change are even more dramatic. For example, when IBM installed a robot to test pin placement for component wiring, the robotic application essentially eliminated the practice of delayed testing of completed assemblies by people using diagnostic software packages. (This robotic application may in turn be replaced by a process for chemically bonding wires to boards, eliminating the need for pins.) As these examples suggest, even stand-alone applications of programmable automation can give rise to radical manufacturing process changes. The more extensive the process change, the more obscure the direct implications for jobs even though the potential impact may be substantially greater.

Process change, with or without automation, often is accompanied or occasioned by a change in product design. * This combination

*James Bright drew the same conclusion about the displacement potential of systems by evaluating conventional automation and the use of computers in the late 1950's and early 1960's. In a paper prepared for the U.S. National Commission on Technology, Automation, and Economic Progress in 1966, Bright noted that the degree of mechanization varied among applications along three dimensions: 1) "span," or use across a sequence of operations; 2) "level," the degree of automatic process control; and 3) "penetration," the extent to which such secondary and tertiary tasks as setup and repair are automated. Bright concluded that "successive advances in automatic capability generally reduce operator duties and hence contributions" (p. 11-210). He observed that sophisticated systems can and will automate conceptual as well as physical work. In contrast, simpler systems tend more to function as tools, complementing the human user. See James R. Bright, "The Relationship of Increasing Automation and Skill Requirements," *The Employment Impact of* Technological *Change,* app. vol. II to the report of the U.S. National Commission on Technology, Automation, and Economic Progress (Washington, D. C.: U.S. Government Printing Office, February 1966).

[6]Steven Ashley, "GE to Install Forging Bin Picker Robot," American *Metal* Market/Metalworking News, June 6, 1983.

[7]OTA case study.

*For example, continuing reductions in computer size reduce the number of parts used in computers, resulting in fewer fabrication and assembly tasks. Also, companies seeking to design products for ease of production are increasingly designing products that can be assembled like "layer cakes," built from the bottom up in layers with no need for upending during assembly. Such design changes reduce production labor with or without automation.

of events generally complicates the analysis of displacement. Most employment forecasts assume constant product characteristics, which imply constant (average) requirements for labor, capital, and materials. The more variables that change, the harder it is to model production and forecast related employment. Furthermore, conventional employment forecasting techniques are ill-suited to evaluate simultaneous changes in product and process characteristics because these potentially involve changes in industry characteristics, such as production scale, number of firms, and number and nature of suppliers.

Task Creation

Although process change may vary in degree, it is the principal reason that programmable automation can also be said to create jobs. Tasks (and thus jobs) are created through technology change in several ways: first, the use of programmable automation may entail more intensive work in some areas. For example, automated systems tend to require more maintenance work than conventional and stand-alone equipment, in part because the cost of a breakdown is much higher. Similarly, CAD and CAE (computer-aided engineering applications of CAD) may stimulate design and engineering activity. As those technologies have made design and product engineering easier and cheaper, employers have hired more engineers.

Second, the introduction of software and integrated databases associated with programmable automation creates a need for new types of support work, such as database management, software maintenance, and programing. Taking the long view, however, some support tasks may only be needed temporarily: The integration of different types of equipment eliminates some of the programing work associated with separate units. This phenomenon is discussed further in a later section of this chapter (see "Transient Skill Requirements").

Third, if buyers want a given product, programmable automation may help producers sell enough to maintain or even increase employment. For example, several small metalworking firms studied by OTA increased their business (and employment) by using NC machinery, which helped them to deliver more quickly and develop better bids.[8] Change in employment levels depends most heavily on the level of demand for different products, which depends in turn on consumer preferences and budgets.

Fourth, the production, distribution, and servicing of programmable automation will also generate tasks and jobs. Since automated equipment sometimes replaces conventional equipment, the net increase in work depends on how much employment falls among producers of conventional equipment. For example, companies may buy robots as an alternative to nonprogrammable materials-handling equipment. The employment potential within the PA-producing industries is discussed in a later section.

Other Task Effects

Programmable automation is also used for tasks people are not well-suited for or likely to do, because the tasks would be too difficult, risky, and/or time-consuming, and consequently too expensive.* One example is the design of integrated circuits, for which computer assistance is considered necessary (although conceivably teams of people at drawing boards could eventually do what individuals at terminals do much more quickly). Similarly, for certain types of complex machining (e.g., for ships' propellers), NC is considered necessary

[8]OTA case study.

*The application of PA to hazardous and unpleasant tasks is discussed in ch. 5, "Work Environment. One example, though, is Chrysler's decision to use a robot to paint the inside of a rninivan. According to the vice president for manufacturing, "It replaces only one guy, so costwise, it will never pay off. But painting the inside of a van is the most miserable job in the plant. " See John Holusha, "Chrysler: New Van and Plant, " *The New York Times*, Oct. 28, 1983.

or preferable. In both cases, the equipment is not totally automatic; human input is required. At this time, programmable automation appears essential for only a relatively few tasks. That set may be enlarged as manufacturers refine and take advantage of PA's capabilities and as totally new products are invented. The inability to forecast such new products again interferes with employment forecasting.

Effects of Programmable Automation on Skills

Programmable automation, through its effects on the tasks performed in manufacturing firms, also affects the types of job skills required for those tasks. In some cases, the creation of new tasks and the elimination of old ones clearly raises or lowers skill requirements. Often, however, the effect on skill demand is ambiguous, because the skills associated with individual jobs and the average skill level of a company's jobs depend on how work is allocated among individuals. Skill demand also depends on how well employers understand what skills they really need. By altering the balance of work between people and machines, PA makes it possible for managers to reallocate work in ways that either raise or lower the skill requirements of jobs.

OTA's appraisal of the effects of PA on the workplace suggests that these technologies will alter both the "depth" and "breadth" of skill requirements. Skill depth refers to the input needed to perform an individual task or group of interconnected tasks, while skill breadth refers to the input needed to perform a set of (nonsimilar) tasks. For example, a journeyman machinist (who sets up and operates machine tools, applying a knowledge of mechanics, mathematics, metallurgy, layout, and machining[1]) has skill depth in the area of machining. Traditionally, subjective notions about which people do skilled work—e.g., craftsmen, professionals, specialists-draw on the concept of skill depth. Skill breadth has traditionally been viewed with more ambivalence—e.g., "jack of all trades and master of none." This is one reason why labor contracts in unionized firms, for example, contain job classifications that define relatively narrowly the requirements and tasks of specific jobs. It is these qualities that govern people's perceptions about whether skill requirements have risen or fallen.

Skill Depth

Skill depth has two dimensions: time to proficiency, and judgment. Jobs comprised of tasks that require little or no time to master (e.g., food service or filing) and limited judgment tend to be low-skilled jobs in which access is broad and pay is relatively low. The longer the time to proficiency, the more likely that formal training is required for hiring and promotion. For example, conventional drafting requires at least 2 years of technical training, while electrical engineering requires at least 4 years of formal training. Although salaried (so-called "white collar") and hourly ("blue collar") work traditionally offer different, usually quite separate, career paths, both types of work include hierarchies of jobs that differ in terms of time to proficiency and judgment, as well as other traits.

Programmable automation seems to lower the time to proficiency and judgment required for many tasks, including those performed by professionals as well as craftworkers. Thus, it

[1] U.S. Department of Labor, Employment and Training Administration, Dictionary of Occupational *Titles,* 4th ed. (Washington, D. C.: U.S. Government Printing Office, 1977).

tends to reduce the need for skill depth in related jobs. Through computerization (and accompanying aspects of mechanical design), automated equipment offers the ability to perform a variety of relatively easy-to-learn tasks (e.g., drawing basic shapes) and increasing numbers of more sophisticated tasks (e.g., process planning). With PA relevant information is, in effect, shared between operators and equipment. People working with automated systems therefore have fewer decisions to make, while those who control the design of a system have more.

Thus, reduction in skill depth is largely due to a shift in emphasis away from complex manual work and toward simpler mental work, but it may involve decreases in both manual and mental tasks. For example, a study comparing early NC machine tools to conventional equipment noted that physical effort was diminished (in an amount depending on the extent of "automation"), demand for motor skills "and the associated perceptual load related to precision and accuracy of movement" were reduced, and the number of operator decisions fell. *

Computerization may affect skill requirements by allowing greater freedom in the allocation of tasks. For example, NC technology allows programing to be separated from machine operation; CNC (computerized numerical control), however, facilitates the combination of programing and operation into a single job. If NC programing is performed by a separate programer, less judgment and proficiency is required for machine operation. As another example, CAD systems are being developed that prevent certain actions, including mistakes.**

*While "conceptual skill associated with the interpretation of symbolic information in the form of drawings, planning instructions and calculations" rose, in more modern NC applications these tasks are often done by the programer rather than the operator. R. J. Hazlehurst, et al. "A Comparison of the Skills of Machinists on Numerically-Controlled and Conventional Machines," *Occupational Psychology*, vol. 43, Nos. 3&4, 1969.

**At least one commercially available system (Computervision's CADDS 4) prevents design detailers from permanently changing designs.

On the other hand, CAD itself may allow engineers to complete designs without the aid of draftsmen.

Since there is less to learn to operate CAD or NC equipment, people with initially lower skills can produce better, faster than they could with conventional technology. Recognizing this, many companies have separated machine operation from NC programing in order to hire less-skilled machine operators instead of high-skilled machinists. However, this is less likely to occur where the product is extremely complex and/or the work less easily shared. OTA's studies of machine shops at both small and large firms show that employers prefer skilled machinists to operate NC machines for complex tasks. It is not clear that further refinement of NC technology will eliminate this need, although it may reduce it. Consequently, it is dangerous to generalize about the impact of PA on skill requirements and staffing.

The removal of skill and the fragmentation of work have always occurred with mechanization. What makes programmable automation different from dedicated, or "hard," automation is the ability to reduce the skill required for specific tasks at higher levels in the organization (see discussions of aircraft company case study in ch. 5).

Skill Breadth

The potential effects of PA on skill breadth, which applies more to jobs or occupations than to single tasks, are less evident than the effects on skill depth. Requirements for the variety of skills in a job are determined by employers, who define specific jobs and hierarchies. PA and other technologies do not force specific forms of work organization; they provide employers with sets of choices about job design and division of labor.

OTA's case studies and other sources suggest that, in some cases, personnel working with PA may require less intimate knowledge of a single process or task but also a general knowledge of more tasks. Among the cases examined by OTA, skill breadth was most required for repair and maintenance personnel. These personnel have been confronted with more varied types of equipment on the job, and with equipment that combines electrical, electronic, and mechanical features. Also, programmable automation calls more attention to production processes, to the linkage (with and without computer-based integration) of activities into systems and of system to system. Consequently, some experts argue that professional, technical, and managerial staff, in particular, require broader familiarity with production activities and their interconnections (as well as an understanding of the means and limitations of computer control).

Skill breadth may be associated with changing job content. A Japanese survey of electrical machinery workers reported that most of these workers found that microelectronics was associated with frequent change in the content of their work.[10] Elsewhere, Japanese researchers concluded from a series of automation case studies that changes in jobs and job content erode the value of experience; one reported solution was to promote experienced workers to various tasks involving watching over equipment.[11]

[10] Denki Roren, "Surveys on the Impacts of MicroElectronics and Our Policies Towards Technological Innovation," paper presented at the 4th IMF World Conference for the Electrical and Electronics Industries, Oct. 3-5, 1983.

[11] Japan Labor Association, "A Special Study Concerning Technological Innovation and Labor-Management Relations," interim report, June 1983.

Effects of Programmable Automation Employment By User Industry

Which people will face changing job opportunities depends on which industries are likely to use programmable automation, when, where, and how, as well as on the capabilities of the technologies. Given the range of potential applications described in chapter 3, it is possible to identify the industries as well as the occupational groups likely to be affected. Indeed, because of its flexibility (and other attributes), PA can be used in a remarkably broad range of industries. In this regard, it is but one manifestation of the growing use of computer technologies taking place throughout the economy. This section will discuss PA users; the employment potential of PA producers (who also tend to be users) is discussed later in the chapter.

The first and principal users of the technologies addressed in this report have been firms in the so-called metalworking industries—primary metals, fabricated metal products, electrical machinery (includes electronics), nonelectrical machinery, transportation equipment, and instruments[12]--particularly the electrical and nonelectrical machinery and transportation equipment industries.[13] Together these industries employed almost 10 million people in 1980; the electrical and nonelectrical machinery and transportation equipment industries employed almost 8 million. Their occupational profiles are shown in table 17. Other industries, including architectural and engineering services, have also begun to be significant users of programmable automation; engineer-

"Industries designated by Standard Industrial Classification (SIC) codes 33-38.

"Ibid. (SIC 35-37).

Table 17.—Occupational Profiles of Manufacturing Industries

Employment in Manufacturing Industries by Major Occupational Group, 1980

Industry	All occupations	Managers and officers	Professional workers	Technical workers	Service workers	Production, maintenance, construction, repair, material handling, and power-plant workers	Clerical Workers	Sales workers
All manufacturting	1000	6 6	6 9	2 9	1 8	681	115	2 2
Food and kindred products	1000	6 4	2 7	7	31	732	100	3 3
Tobacco products	1000	5 9	3 7	1 9	3 5	72.8	105	1 2
Textile mill products	1000	3 7	1 7	9	2 2	8 1 9	8 8	9
Apparel and other textile products	1000	3 6	1 2	2	1 2	832	91	14
Lumber and wood products, except furniture	1000	6 2	1 5	8	21	81 4	64	1 7
Furniture and fixtures	1000	5 3	2 2	8	1 9	764	11 1	2 3
Paper and allied products	1000	5 3	4 3	1 5	1 7	743	105	24
Printing and publishing	1000	101	9 9	10	1 7	488	21 1	74
Chemicals and allied products	1000	9 8	123	5 3	2 2	526	1.16	32
Petroleum refining and related industries	1000	7 3	9 4	3 1	1 5	628	11 .1	45
Rubber and miscellaneous plastics products	1000	6 5	4 1	1 7	1 6	751	9 5	15
Leather and leather products	1000	3 9	1 4	3	1 3	806	104	23
Stone clay glass and concrete products	1000	7 3	31	1 4	1 4	756	9 0	20
Primary metal products	1000	3 9	3 8	1 9	2 0	794	8 2	9
Fabricated metal products	1000	6 6	4 2	21	1 6	737	9 8	19
Machinery except electrical and transportation equipment	1000	7 8	9 4	5 4	1 6	607	133	1 8
Electrical and electronic machinery	1000	6 4	123	6 2	1 4	603	123	1 0
Transportation equipment	1000	5 8	131	3 9	2 2	647	9 7	5
Instruments and related products	1000	8 7	116	7 4	1 7	537	149	1 9
Miscellaneous manufacturing industries	1000	7 7	3 5	1 5	1 7	688	14 1	2 8

Percent Distribution of Employment in Manufacturing Industries by Major Occupational Group, 1980

Industry	Managers and officers	Professional workers	Technical workers	Service workers	Production maintenance construction repair material handling and powerplant workers	Clerical workers	Sales workers
All manufacturing	1328,160	1404080	594270	373150	13767 040'	2322400	438710
Food and kindred products	107750	45,360	12000	52000	241 080	69730	66910
Tobacco products	3,780	2,380	1220	2,230	46270	6960	760
Textile mill products	31,980	14,710	7,750	19,110	713,410	76,780	7,040
Apparel and other textile products	45,820	15,500	2,250	15,290	057,890'	16 190	18.420
Lumber and wood products except furniture	41,0701	9,8901	5,090	13,520	534,720	41,920	11060
Furniture and fixtures	24,3001	10,200	3 610'	8,510	348,250	50490	10470
Paper and allied products	37,3401	30,190	10,500	11,570	519530	73240	16540
Printing and publishing	26,8301	124,2701	12,620	20,980	612420	264,290	92890
Chemicals and allied products	10000	137650	58,990	24700	5875201	162670	35290
Petroleum refining and related industries	14,7901	19,030	6,290	3080	1272901	23040	9170
Rubber and miscellaneous plastics products	45,860	28,880'	12,190	11420	534150	67470	11 020
Leather and leather products	9,130	3,390	720	3030	190440	24640	4840
Stone clay glass, and concrete products	48,720	20,930	9,580	9520	503440	60 1313	13310
Primary metal products	47,550	46,350	22,3201	23540	956430	98230	10680
Fabricated metal products	103,670	67,110	33,650	25750	1,164180	154,800	30800
Machiney, except electrical and transportation equipment	195,630	234,740	134,550	39,9-00	1 515640	332493	44 140
Electrical and electronic machinery	133,520	255,880	129,720	29,310	1,254920	255,900	20390
Transportation equipment	106,320	240,400	72,110	40,480	1,168110	178,180	9470
[instruments and related products	61,500	82,460	52,840	12130	381,320	105,970	13 540
Miscellaneous manufacturing industries	32,400	14760	6,270	7,0801	290,0301	59280	11 970

SOURCE Bureau of Labor Statistics, *Occupational* Employment *in Manufacturing Industries* Bulletin 2133 September 1982 ing and architectural services employed 557,000 people in 1980.[14]

Application of the PA technologies will grow relatively quickly among these early users. Their experience will facilitate further application of PA, including the integration of systems. For example, GM's widely publicized plan to have over 14,000 robots by 1990 reflects not only the firm's size, but also its experience with robots and its understanding of how and where to use them. Because use of automated production technologies, in particular, will probably remain concentrated in these industries through this decade, principal near-term employment impacts will also be concentrated in these industries.

Programmable automation will be applied in a growing variety of industries because of improving capabilities, falling costs, and growing experience with particular applications, as well as the perceived effect on competitiveness. Materials handling, assembly, simulation, and inventory control applications can be used across the manufacturing sector; this contrasts with the more narrow market for robotic spot welding and spray painting, NC machining, and CAD for electronic equipment. Already, industries such as food processing, textiles, apparel, and paper manufacturing have begun to explore use of programmable automation, especially robots. Applications of these technologies will spread both within the manufacturing sector and outside of it, but sufficiently slowly that significant effects on employment outside of the metalworking industries are unlikely before 1990.

Some perspective on the unevenness of technology diffusion, and its impact on employment by industry, can be gained from data on the spread of NC technology. In 1968, only 0.5 percent of machine tools in use among metalworking industries in general were numerically controlled. The percentage was only slightly higher for nonelectrical machinery industries. In the 1976 to 1978 period, the overall figure was 2.0 percent, varying among industries from 0.3 percent for metal stampings to 5.3 percent for aircraft and parts. The overall figure was 4.7 percent by 1983. These figures underscore the fact that production technologies tend to spread slowly and unevenly. Within the machine-tool industry itself, the proportion of NC machine tools was 2.6 percent in 1973, 3.7 percent in 1976-78, and 6 percent in 1983.[15]

Firm size may affect the incidence of employment impacts within and across industries. To date, most users of PA, especially the production technologies, have been large firms. Such firms may continue to dominate as users because they can more easily purchase equipment, buy or build on previous know-how, and otherwise afford to automate.[16] Industries dominated by large firms may therefore experience faster employment change than industries dominated by smaller firms, other things being equal; the changes will come in larger doses. On the other hand, larger firms generally have more capacity to transfer and retrain displaced personnel, making layoffs less likely. Also, supplier-buyer links between large and smaller firms may hasten the adoption of programmable automation by smaller firms.* The domination of the aerospace and auto industries by a few large firms linked to

[14] Bureau of Labor Statistics, "Employment by Industry and Occupation, 1982 and Selected 1995 Alternatives," unpublished data on wage and salary employment, 1983.

[15] "The 13th American Machinist Inventory of Metalworking Equipment 1983," *American Machinist*, November 1983; and National Machine Tool Builders' Association, 1983-84 *Handbook of the Machine Tool Industry.*

[16] Steven M. Miller, *Potential Impacts of Robotics on Manufacturing Costs Within the Metalworking industries*, doctoral dissertation, CarnegieMellon University, 1983.

*So, too, will improvement of low cost systems aimed at smaller users.

a number of smaller suppliers can heighten the employment impacts within those industries. *

Geographic Incidence

Programmable automation will exacerbate employment problems in certain geographic areas in the short term (i.e., the 1980's). In the longer term, however, its impacts will be more general.

Given the differing tendencies of different industries to use programmable automation, employment in the East North Central and Middle Atlantic regions, plus individual States such as California and Texas, are most likely to be affected during this decade, as well as the next. Employment in such metalworking industries as automobiles and nonelectrical machinery is concentrated in the East North Central region, especially in Ohio, Michigan, and Illinois; the Middle Atlantic region is a major source of industrial machinery; California and Texas are major sources of electrical machinery and aerospace products. See figure 15 for a comparison of regional differences in manufacturing employment. These areas include the six States that had 5 percent or more of their employment in manufacturing and together held over 42 percent of all manufacturing employees, according to the 1977 Census of Manufacturers (latest version available)—California (9 percent), New York (8 percent), Pennsylvania (7 percent), Ohio (7 percent), Illinois (7 percent), and Michigan (6 percent).

In the short term, areas most dependent on single firms or industries will be the most vulnerable to the effects of employment change. As the authors of an OECD study of job losses in major industries across countries noted, "the proportion of the community's workers involved in the primary cutbacks' is the principal determinant of the effect of displacement and unemployment on a community. '7 This proportion, and a related factor, the diversity of the local economy, both affect the ability of the local labor market to absorb displaced workers. Such vulnerability, however, exists independently of PA or any other technology; lack of economic diversity has long been known to make local economies vulnerable to any changes in hiring by dominant employers. As table 18 shows, States with a lot of manufacturing were likely to have experienced above-average unemployment over the past 7 years, although other States also experienced high unemployment.

The East North Central region is particularly likely to experience unemployment because of its association with the auto industry. That industry is not only a major user of programmable automation, but is also particularly sensitive to import competition and to changing consumer car-buying behavior. Consequently, even before the auto industry's use of robots was attracting much publicity, there was speculation that industry employment might not re-attain the peak levels achieved in 1978 and 1979. The same area is also experiencing job losses associated with other industries, such as the industrial, farm, and construction machinery industries. These industries are not only automating but have also been contracting due to import competition and the cyclical declines in business.

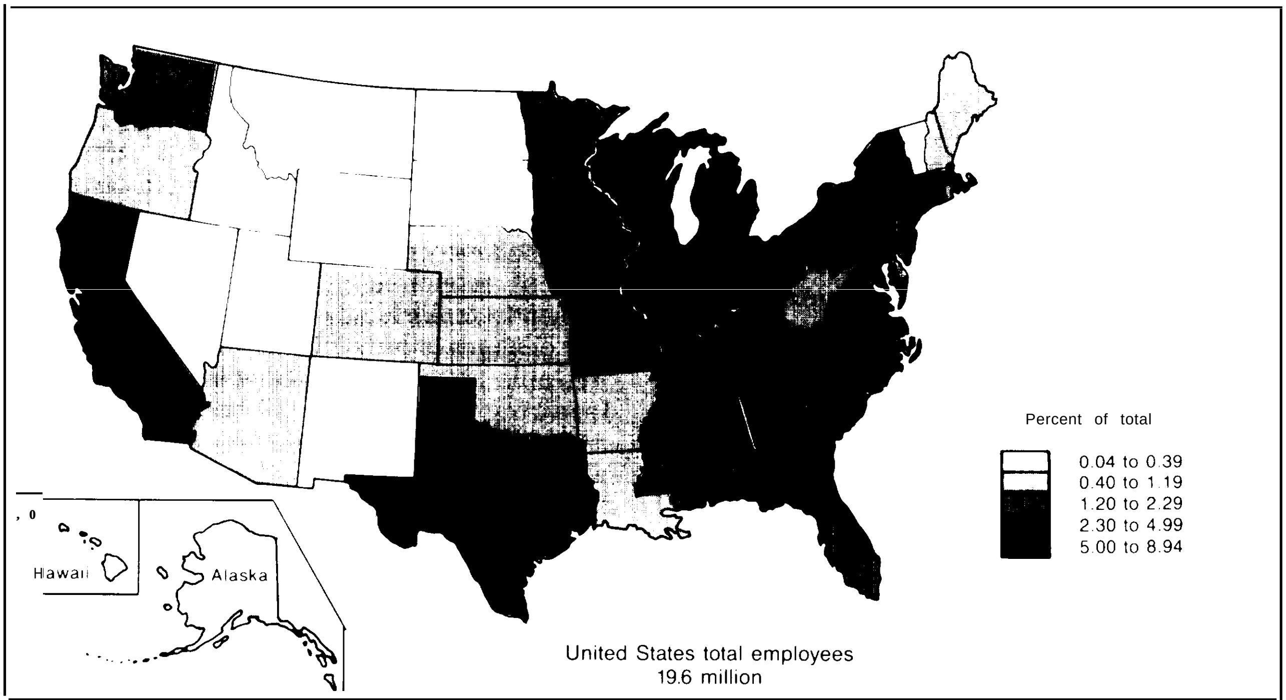
Increasingly, the employment impacts of programmable automation will become dispersed because of the broadening geographic distribution of manufacturing activity. Over

*On the other hand, the movement among major metalworking firms toward using fewer suppliers (to improve quality control) may shift supply business toward larger firms. which may have a greater propensity to automate. The extent of this movement varies among industries. It is especially pronounced in the auto industry, for example. See Nancy Kingman, "OEMs Plan to Utilize Fewer Supplier Firms, " *American Metal Market Metalworking News*, Oct. 10, 1983.

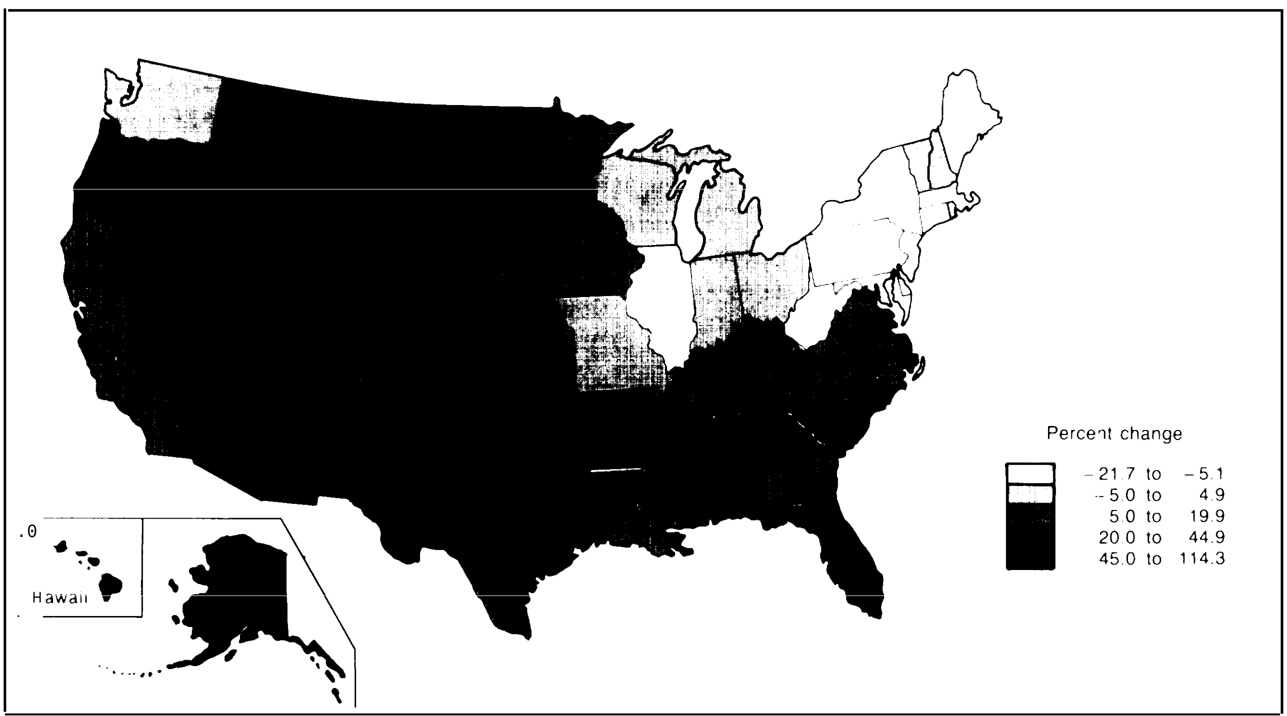
[17]Robert B. McKersie and Werner Sengenberger, *Job Losses in Major Industries* (Paris: OECD, 1983).

Figure 15.– Regional Manufacturing Employment

Employment as a percent of U.S. total, by State: 1977



Change in employment, by State: 1967-77



SOURCE U S Department of Commerce Bureau of the Census

Table 18.—Unemployment Rates by State,[a] 1976-82

	1976	1977	1978	1979	1980	1981	1982
Annual average rate (%)	7.2	6.7	5.7	5.6	6.9	7,3	9.3

Distribution of State unemployment relative to averege

Number of years above average	Number of States	Identity of States
0	14	Colorado, Iowa, Kansas-, Minnesota, Nebraska, New Hampshire, North Carolina, North Dakota, Oklahoma, South Dakota, Texas, Utah, Virginia, Wyoming
1	2	Maryland, Montana
2	4	Connecticut, Georgia, Missouri, Vermont
3	5	Kentucky, Massachusetts, Nevada, South Carolina, Wisconsin
4	6	Arizona, Florida, Hawaii, Idaho, Illinois, Indiana
5	7	Arkansas, Louisiana, Maine, New Jersey, New Mexico, Ohio, Tennessee
6	4	California, Delaware, Mississippi, New York
7	9	Alabama, Alaska, District of Columbia, Michigan, Oregon, Pennsylvania, Rhode Island. Washington. West Virginia
	51	

[a]Including the District of Columbia

SOURCE U S Department of Labor Bureau of Labor Statistics Current Population Survey

the last two or three decades, manufacturing has grown in the South and in the Western regions of the country, aided in part by government spending. Between 1960 and 1970, the number of manufacturing employees in the Northeast was almost constant, while in all other regions it grew substantially. Between 1970 and 1980, manufacturing employment fell in the Northeast, remained constant in the North Central region, and grew relatively rapidly in the South and West. By 1980, over 43 percent of manufacturing employment was in the South and West regions.[18]

The growth in manufacturing employment in the South and West reflects lower production costs in those regions compared with the Northeast and North Central, as well as a growth of the aerospace and electronics industries in California and several Southern States. These areas have benefited from space program funding in the 1960's and defense program funding since the 1950's. Between 1951 and 1976, for example, the South's share of military prime contract awards rose from 11 to 25 percent, while the West's share grew from 16 to 31 percent. " Defense and space R&D has, in turn, led to commercial manufacture of such associated products as calculators and semiconductors being concentrated in the same regions.

The dispersion of manufacturing does not, however, preclude regional variation in the rate and type of technology change. A recent study of geographic patterns in the use of metalworking equipment found:

> The more advanced production technologies are being introduced in the higher skill, higher wage areas of the industrial Midwest while less of these technologies or less advanced versions are being introduced to a lesser degree in the low wage, lower skill labor markets of the South and West.[20]

The authors suggest that there is a "matching of capital with labor by region, " a phenomenon that will influence the geographic incidence of technological displacement and associated unemployment.

The dispersal of manufacturing activity and the growth of service industries among regions have allowed regional economies to diversify. This has made most regions less sensitive to changes in manufacturing employ merit.* One

[18]James A. Orr, Haruo Shimada, and Atsushi Seike, "U, S.-Japan Comparative Study of Employment Adjustment, " draft, U.S. Department of Labor and Japan Ministry of Labor, Nov. 9, 1982.

[19]Eileen Appelbaum, " 'High Tech' and the Structural Unemployment of the Eighties," paper presented at the American Economic Association Meeting, Washington, D. C., Dec. 28, 1981.

[20]John Rees, et al., "The Adoption of New Technology *in* the American Machinery Industry, " Occasional Paper No. 71, Maxwell School of Citizenship and Public Affairs, Syracuse University, August 1983.

*Note, however, that encouragement of just-in-time supply systems by the auto and other industries may encourage recentralization (for the auto industry, at least, in the Midwest).

indicator of how widely PA use is dispersed is the distribution of service centers and demonstration facilities established by vendors. Vendor literature and the trade press suggest that such facilities are distributed quite broadly across the country.

Another influence on geographic incidence is the combination of PA with advanced telecommunications systems linking facilities across a region or even across countries. For example, Lockheed has found that its use of CAD and CAM has affected its interfacility activity.

> Inter-company use of CADAM-generated data through an interactive system using satellites allows for the transmission of CADAM models between four Lockheed companies that are now on-line. Once the remaining companies have been added to the network, said [a Lockheed official], "we can design at one plant, program at another and manufacture at still another plant."[21]

Automation producers face similar prospects. For example, ASEA Robot Co. has facilities in Detroit, White Plains, New York City, Houston, and Los Angeles, and it installs robots around the country. It adopted a communications system "that will allow ASEA engineers in New Berlin (Wis.) to work directly with technicians installing equipment anywhere in the nation' through computer connections.[22] Computer and telecommunications links, together with PA systems, enable manufacturers to spread a given complement of personnel across a large geographic area and avoid fully staffing separate local facilities.

There is also an international dimension to geographical impacts. In particular, the availability of programmable automation may influence manufacturers' decisions about locating production in the United States or abroad. Some proponents of PA argue that a principal benefit may be to stem or reverse the exodus of manufacturing jobs to other countries. There is some evidence that the cost-reducing effect of PA has motivated companies to locate more electronics facilities in the United States than they might have previously. For example, GM-Delco recently expanded U.S. production instead of going overseas.[23] Also, AT&T attributes its plans to consolidate most of its consumer telephone manufacturing within the United States to automation, as well as to the benefits of domestic location for responsiveness to changing technologies and consumer preferences. According to an AT&T official:

> Far East, Central and South American labor rates are low , . . but we are designing and building our products for automated assembly, displacing labor with capital . . . Changes in our manufacturing operations generally represent changes in technology—moving from electromechanical phones to electronic phones. Because that technology has spread throughout the product line, and a high percentage of the value added in a product line is electronics, we are able to use automated assembly instead of the human assembly line.[24]

However, cost is not the only reason why producers choose to locate offshore. Where producers are motivated by a desire to be near a foreign market, especially if local-content laws there require local production, no reduction in costs at home will keep such production in the United States. Thus, auto and electronics producers continue to operate, expand, and buy from overseas production facilities. Digital Electronic Corp., for example, expects that half of its materials requirements will be filled by overseas sources over the next 3 to 5 years, whereas 15 percent is now.[25] If, on the other hand, programmable automation encourages more small-batch production of goods aimed exclusively at the domestic market, es-

[21] "Lockheed Exec: 30B Automation Market by 1990, " *American Metal Market/Metalworking* News, Sept. 26, 1983.

[22] Robert Fixmer, "Swedish Robots Pick Wisconsin" (Madison), *Capital Times*, Mar. 5, 1983.

[23] John Holusha, "G. M. Electronics Back in U. S," *The New York Times*, June 20, 1983.

[24] Laurel Nelson-Rowe, "AT&T Shifting More of Its Consumer Phone Manufacturing to U.S., " Communications Week, Jan. 30, 1984.

[25] Nancy Kingman, "OEMs Plan to Utilize Fewer Supplier Firms, " *American Metal Market/Metalworking News*, Oct. 10, 1983.

pecially goods tailored to specific regional or ethnic preferences, then domestic manufacturing may benefit even if overseas locations remain most economical for mass production. * Insofar as multinational corporations standardize products across companies or draw on standard components, it may be harder to isolate production for the U.S. market from production for world markets. This prospect has been raised by the discussions of the "world car. "** It is also becoming an issue for production of automation hardware (see ch. 7).

*The time-savings benefits of computerized apparel equipment may help domestic firms compete with importers because they can deliver more quickly. "When a customer can order something and have it in his store in 2 weeks, there's no way the imports can compete, " according to one clothing maker. See Fran Hesser, "Clothing Makers Try to Sew Up Labor Costs, Foreign Competition, " *The Atlanta Constitution,* Sept. 21, 1983.

**Ford, for example, has a computer and communications system linking engineers in Europe and the United States for automotive design and analysis work. "Computer-Aided Engineers: Worldwide Dedicated Computers Analyze Into Structures, " *Tooling and Production,* October 1983.

Effects of Programmable Automation on Occupational Employment

Occupational impacts of individual automation technologies and of accompanying major process changes will vary enormously among industries. In the absence of detailed company and industry studies of the deployment of labor across the economy, data on employment by occupation are the only means of counting people potentially exposed to the risk of displacement. * They can also be used to develop inferences about new jobs and occupations. Such estimates, it must be understood, are rough at best.

Selected Detailed Occupational Groups

Engineers

In many ways, engineers are a central factor in the employment changes expected to occur with programmable automation. Engineers develop automation technologies; they work with them; yet they are not immune to being displaced by them.

Engineers contribute to both the production and use of PA. The mix of engineers by discipline found in an enterprise varies with the nature of the product or research topic; but in general, electrical/electronic and mechanical engineers design equipment and systems, and industrial/manufacturing engineers as well as electrical and mechanical engineers design applications. Different industries have different needs for special engineering disciplines, such as aeronautical/astronautical, chemical, and metallurgical engineers. Typically, employers prefer that engineers have at least a bachelor's degree, although individuals without such training can be certified by the Society of Manufacturing Engineers to perform certain types of production engineering, and sometimes individuals attain the title of engineer through promotion from other positions. Engineers who perform research usually hold advanced degrees. The employment share of manufacturing engineers with degrees reflects the fact that employers and schools alike have historically held this engineering discipline in lower regard than others (although this view is changing, as discussed later).**

CURRENT EMPLOYMENT TRENDS

Total employment of engineers in 1980 was over 1.1 million, including about 580,000 employed in manufacturing. In 1982, nearly

*Such data are principally available through the Bureau of Labor Statistics (BLS), although some are also available from the Bureau of the Census, the National Science Foundation, and from private sources. Most data presented in this chapter are for 1980, which represents essentially prerecession conditions and conditions prior to much of the recent growth in PA use.

** N. b., statistics collected by BLS treat manufacturing engineering as a subset of industrial engineering, although in the vernacular the term industrial engineer has a more limited meaning.

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590,000 engineers were employed in manufacturing industries.

Engineers have become more prevalent in manufacturing industries over the past several years. Sectoral employment of engineers grew despite the recessions, although individual industries suffered declines in engineering employment between 1980 and 1982. Engineers comprise nearly a third of professional and technical personnel across the manufacturing sector. The electrical and noneletrical machinery, transportation equipment, and a few other relatively technology-intensive industries (e.g., instruments and chemicals) together employ over 80 percent of the engineers working in manufacturing industries.[26] The number and distribution of engineers reflects many factors, particularly changes in process technology and patterns in defense spending (the principal factor behind employment trends for aeronautical engineers). See table 19. The relatively large growth in electrical engineering employment, for example, reflects the spread of microelectronics across various products and processes.

Technology change and other factors are causing growth in design and production engineering activity, which in turn supports growth in demand for engineers. In some cases, programmable automation is merely a vehicle for engineering activity motivated by other factors; in others, the nature of PA itself is a cause of growth in engineering. The use of CAD, for example, may be associated with increased design engineering activity because it makes design cheaper and therefore easier to do more often.* This is especially likely in industries (e.g., special semiconductors) where product differentiation and customization are increasingly important. In some industries (e.g., computers and aerospace), CAD/CAE facilitates faster advances in product technology, allowing more (and more complex) products to be introduced in a given period of time.**

Design requirements of FMS and automated storage and retrieval systems (AS/RS) are increasing producer needs for engineers. Cincinnati Milacron, for example, reports using thousands of engineering hours to analyze FMS needs of potential customers.[27] Across manufacturing generally, production engineering activities are growing because programmable automation and market factors are focusing attention on product quality, production processes, and the links between design and production. The growth of PA products and markets is itself a source (albeit limited) of increased engineering design and production activity and employment. The more complex the application of PA, and/or the greater the change in the production process, the greater the investment in engineering will be.

As was suggested earlier, the spread of programmable automation influences the mix of engineers. In particular, it is contributing (because of changes in materials technology, as well as the growing concern with manufacturing processes) to a revival of interest in the discipline of manufacturing engineering; schools report greater interest among students

[26]"Changing Employment Patterns of Scientists, Engineers, and Technicians in Manufacturing Industries: 1977 -1980," National Science Foundation, 1982.

*This would be similar to the experience with computer-based technologies for financial services, the adoption of which was associated with growth in certain banking transactions.

**According to Clarence Borgmeyer of Pratt & Whitney Aircraft, "It takes us approximately as long to design an engine as it did in 1956, but engine technology has grown infinitely more complex. We couldn't begin to solve today's problems with yesterday's computers. " See "Maker of Aircraft Engines Ties Data Base to CAE Applications on Divisional Scale, " *Computerworld*, Sept. 12, 1983.

[27]Lauri Giesen, "Industry Interest Sparks FMS Sales Hopes for '84, " *American Metal Market/Metalworking News*, Dec. 5, 1983.

Table 19.— Number and Distribution of Engineers, 1980

	All manufacturing		Metalworking machinery and equipment		Office, computing, and accounting machines		Electrical industrial apparatus		Electronic components and accessories		Motor vehicles and equipment		Aircraft and parts	
Engineers	579,677	2.3%	11,930	3.2%	48,303	11.2%	10,602	4.5%	34,077	6.1%	17,804	2.3%	75,587	11.5%
Electrical	173,647	0.9%	1,671	0.5%	31,008	7.2%	5,818	2.4%	23,591	4.2%	466	0.1%	5,367	0.8%
Industrial	71,442	0.4%	1,963	0.5%	6,125	1.4%	1,414	0.6%	3,031	0.5%	3,921	0.5%	5,809	0.9%
Mechanical	122,328	0.6%	6,718	1.2%	3,970	0.9%	2,128	0.9%	2,769	0.5%	3,959	0.5%	11,364	1.7%

SOURCE: Bureau of Labor Statistics, "Employment by Industry and Occupation, 1980 and Projected 1990," unpublished data on wage and salary employment.

in pursuing a manufacturing engineering major. Also, because of their dependence on systems analysis and the need for development of computer hardware and software, PA producers and users alike appear willing and able to substitute computer scientists and systems analysts for engineers. PA is thus likely to have similar employment impacts on engineers and systems analysts because of their overlapping responsibilities, although systems analyst employment is lower overall* (see table 20).

A review of want-ads published by PA producers and users over the last 2 to 3 years shows that companies generally list engineering and computer science degrees as alternative criteria for eligibility when recruiting for both product and applications development positions. Among engineering degrees desired, electrical engineering is listed most frequently, closely followed by mechanical engineering.

Flexible hiring criteria reflect in part a growth in interdisciplinary work among engineers. Production and use of PA equipment help to spur interdisciplinary engineering because PA combines electrical, electronic, and mechanical systems technologies. In addition, design and production activities often merge with the use of PA systems, especially CAD/CAE systems that allow for analysis of production requirements and processes.

*In 1980, 42,404 computer systems analysts were employed in manufacturing. While manufacturing's share of computer systems analyst, operations analyst, and systems analyst employment fell overall during the 1970's, the proportions employed by metalworking industries generally rose. Between 1970 and 1978, the percent employment of computer specialists rose for all manufacturing (and for all industries combined), and in metalworking industries, while the proportions of engineers and engineering and scientific technicians fell slightly.

Table 20.—Employment of Computer Systems Analysts, 1980

	Number	Percent
All industries	**201,999**	**0.20%**
All manufacturing	42,404	**0.20**
Metalworking machinery and equipment	336	0.09
Office, computing, and accounting machines	6,913	1.60
Electrical industrial apparatus	581	0.24
Electronic components and accessories	1,146	0,20
Motor vehicles and equipment	945	0.12
Aircraft and parts	3,535	0,54

SOURCE: Bureau of Labor Statistics, Employment by Industry and Occupation 1980 and Projected 1990, unpublished data on wage and salary employment.

The rise in interdisciplinary engineering and systems analysis suggests that college training for production engineers may become increasingly necessary over time—i.e., it may become more difficult for individuals lacking college degrees to rise through the ranks and obtain engineering jobs. Confirming this assumption, 6,600 manufacturing engineers predieted in a 1979 survey that 50 percent of plant work forces in the automated environment will be engineers and technicians. Interestingly, while 49 percent of all respondents had at least a B. A., 61 percent of those between 20 and 29 years of age did.[28] However, recent want-ads suggest that, at least among today's users of programmable automation, employers may be willing to accept several years of relevant experience in lieu of a technical college degree for some engineering positions.

The growth in engineering activity caused by or accompanying programmable automation will not necessarily raise engineering employment among user firms, although it may raise it elsewhere. Many users appear to favor *turnkey* purchases and rely on vendors to meet occasional needs for applications engineering, rather than expand their own staffs. The Upjohn Institute, for example, found this to be the case among robot users generally.[29] Also, applications engineering services are available from growing numbers of third-party engineers employed in consulting and service firms. These engineers may substitute for in-house staff for either producers or users, performing applications engineering and planning (and sometimes contributing to product development). For example, increasing numbers of programmable con-

[28] "The Manufacturing Engineer: Past, Present and Future," special report to the membership of SME, May 28, 1979.
[29] H. Allan Hunt and Timothy L. Hunt, *Human Resources Implications of Robotics*, The W. E. Upjohn Institute for Employment Research, 1983.

troller installations are handled by third-party firms.[30]

Engineering employment in engineering services firms has been growing generally, and if PA consulting and service firms continue to thrive, the share of engineers employed in manufacturing firms (per se) may continue to fall. Although the proportion of manufacturing professional and technical employees represented by engineers has been rising, the proportion of engineers employed in the manufacturing sector is declining. Between 1970 and 1978, the manufacturing sector share of engineer employment fell from 54 to 50 percent, while the (miscellaneous) service share rose from under 13 to 17 percent (see table 21). Within the service sector, engineering employment is concentrated in the engineering and architectural service industry (a group including a large proportion of self-employed professional engineers). That industry was the largest employer of engineers in 1982.[31]

Table 21.—Percent Distribution of Engineering Employment by Industry Group, 1970 and 1978

Economic sector	1970	1978
Agriculture, forestry, and fishing	0.18	0.27
Mining	1.73	2.40
Construction	8.29	7.08
Manufacturing	54.26	50.08
Durables	45.82	42.16
Primary metals	2.2	2.01
Fabricated metals	2.46	2.44
Machinery, except electrical and transportation equipment	8.31	8.80
Electrical and electronic machinery	13.23	12.37
Transportation equipment	11.97	10.53
Automobiles	2.17	2.40
Aircraft	8.53	7.02
Professional and scientific instruments	2.36	2.48
Transportation, O.P.U.[a]	7.99	8.55
Wholesale and retail trade	4.32	4.44
Finance, insurance, and real estate	0.71	0.75
Services	12.73	17.01
Commercial R&D	1.06	1.42
Engineering and architecture	7.04	9.63

[a]Other public utilities

NOTE Percentages do not sum to 100 due to exclusion of government employment figures

SOURCE: U S Department of Labor, Bureau of Labor Statistics, *The National Industry-Occupation Employment Matrix, 1970, 1978, and Projected 1990*, April 1981

PROJECTED EMPLOYMENT IMPACTS

OTA's case studies and other evidence suggest that, while demand for engineers will increase during this decade, automation will eventually dampen the rate of growth of their employment in manufacturing industries. This is likely because: 1) computer-aided design and engineering increases the output per engineer;* 2) anticipated improvements in such areas as equipment interfaces will solve some of today's problems in applications engineering; and 3) in the long term, if not sooner, there may be some substitution of technician jobs for engineering jobs (see the next section).

Although the complexity of PA installations will grow, so will the capability of automated engineering aids, such as simulation systems, to deal with this complexity. A major aerospace firm, for example, has predicted that its engineering and related technical staff requirements may fall by as much as one-third once the company achieves its automation goals; for some production engineering tasks, the drop may be as high as 80 percent.[32] The aerospace industry represents an extreme case, because the complexity and the stringent quality standards of aerospace products will probably drive major aerospace firms to greater levels of computerization and systems integration, and on a faster timetable, than firms in other industries.

Various trends in industrial organization will also work to slow the rate of growth in engineering employment. For example, the growth in engineering consulting and service firms means that fewer engineers will be employed than would be if producers and users satisfied their needs for engineers internally.

[30]OTA case study.

[31]Ronald E. Kutscher, "Future Labor Market Conditions for Engineers," paper prepared for the National Research Council Symposium on Labor-Market Conditions for Engineers, Feb. 2, 1984.

*For example, Chrysler expects that its expanded use of CAD will not lead to expansion in employment of engineers and designers using the technology. Rather, the company expects to devote time saved in design and analysis to such other tasks as tooling and product testing. See "Chrysler Expanding CAD Network," *Automotive News*, July 12, 1982.

[32]OTA case study.

Indeed, recent and anticipated growth in engineering and architectural service firms has been attributed in part to shortages of certain types of engineers-in effect, fewer engineers can be spread more thinly by this means .33 Another factor is growth in the number of automation users who also produce automated equipment and systems. Such user-producers will draw on engineers involved with their own use of automation to produce automated equipment and systems. One reason that Westinghouse, for example, decided to enter the robot market was management's realization that it already had vital in-house engineering expertise.[34] Moreover, when Westinghouse acquired Unimation, it consolidated its robotics work force, since the combined forces of the two firms were believed to be too large.[35]

SHORTAGES OF ENGINEERS

In the near term, engineering employment depends primarily on market conditions and defense spending. Thus, even though they "need" engineers to develop new products, machine-tool builders have laid off engineers because of depressed sales; also, recent engineering graduates have had difficulty getting jobs because of the recessions.[36] Historically, engineers have undergone cycles of shortage and surplus; despite ambiguous evidence, many in industry now believe that a shortage of engineers does or will exist. For example, the Electronic Industries Association recently forecast a shortage of 113,000 electrical and computer engineers by 1987, based on forecasts of engineering graduates and employment targets reported in a survey of 815 manufacturing facilities employing over 736,000 people.[37] However, employer survey data are generally considered unreliable by employment analysts. The shortcomings of this particular survey, for example, were addressed at the February 1984 National Research Council Symposium on Labor-Market Conditions for Engineers.

Drawing on more comprehensive data, the National Science Foundation (NSF) has concluded from a forthcoming study of science, engineering, and technician (SET) personnel needed by defense and civilian industries between 1982 and 1987 that (under conservative assumptions regarding the supply to SET occupations):

1. the only engineering discipline that will experience a shortage, regardless of macroeconomic conditions and defense expenditures, is aeronautical/astronautical (although the sharp drop in the market for aero/astro engineers in 1982-83 may have made this less Likely);
2. under stagnant economic conditions and with low defense expenditures, no other engineering discipline will experience a shortage; and
3. with economic growth and high defense expenditures electrical engineers might be in short supply .38

NSF and others note that even for a specialized occupational category such as engineers, the supply of labor includes new graduates and immigrants. It also includes movement in from other occupations and movements between disciplines. Such in-mobility is easier for some disciplines (e.g., electrical and electronic) than for others (e.g., aeronautical and astronautical) among engineers.[39]

[33] *U.S. Industrial Outlook,* Washington, D. C., 1983.

[34] Laura Conigliaro and Christine Chien, "Computer Integrated Manufacturing, " Prudential-Bache Securities, Aug. 2, 1983.

[35] " Westinghouse Revamps Robotics; 40 Jobs Lost, " *Chicago Sun-Times,* May 22, 1983.

[36] Lauri Gieson, "Engineering Layoffs Raise Questions About the Domestic Industry's Future Strength, " *American Metal Market/Metalworking News,* June 18, 1983.

[37] Bill Laberis, "Study Predicts Major Engineer Shortage, " *Computerworld,* July 11, 1983.

[38] "Projected Employment Scenarios Show Possible Shortage in Some Engineering and Computer Specialties, " *Science Resource Studies Highlights,* National Science Foundation, Feb. 23, 1983. Also, note that "existing Federal programs do not collect data on shortages of workers in specific occupations; such data would be very expensive to collect and because of their complexity their reliability would be questionable. See Neal H. Rosenthal, "Shortages of Machinists: An Evaluation of the Information, " *Monthly Labor Review,* July 1982.

[39] Jean E. Vanski, "Projected Labor Market Balance in Engineering and Computer Specialty Occupations: 1982 -1987," paper prepared for the Symposium on Labor-Market Conditions for Engineers, National Research Council, Feb. 2, 1984.

Several factors may explain the differences in perception about engineer availability. For the purposes of this study, a principal factor appears to be that employers desire personnel with very specific skills and experience, qualities that data available to modelers (and surveys tallying employment goals) may not reveal. For example, a recruiter from Xerox recently observed:

> We're looking for hardware design engineers and some software people . . . Many of the resumes we see are from people right out of school. Unfortunately, there's nothing for them.[40]

Because it takes time to train engineers and for them to acquire relevant experience, this problem is hard to overcome, especially where technologies are changing rapidly. Furthermore, there is no way to objectively measure the ability of employers to make do with second-choice job candidates, or to restructure their work. On the one hand, such steps bring labor supply into balance with demand. On the other hand, they raise questions about the adequacy of the quality of labor used to meet occupational demands. Also, employees may prefer graduates with the highest grades and/or those from the top schools, a group obviously much smaller than the total graduate pool.

In time, employers may well find that a combination of fewer engineers and automated engineering aids will help them to stabilize their engineering work forces and overcome labor quality problems. Such an approach appears to be taken now with production workers; it may come later for professional and technical workers.

Technicians

A variety of technological and economic factors are contributing to the growth of technician employment in industry; the growing numbers and responsibilities of technicians suggest they are the new "skilled workers" of the economy.

CURRENT EMPLOYMENT TRENDS

Technicians employed in industry are classified as engineering, science, health, or other (not elsewhere classified). Engineering technicians, the principal group within durable manufacturing, include the categories of draftsmen, electrical/electronic engineering, industrial engineering, mechanical engineering, other engineering; NC tool programmers may also be considered engineering technicians. computer programmers (business, scientific, and technical) are another important class of technicians in the manufacturing industry. In 1980, combined employment of engineering technicians, NC tool programmers, and computer programmers was about 1.3 million; it was about 508,000 in manufacturing. In 1982, the total-industry and manufacturing levels were 1.5 million and 518,000, respectively (see table 22).

PROJECTED EMPLOYMENT IMPACTS

Technicians are becoming prominent in PA applications engineering. For example, one company visited by OTA has developed a number of robot applications by teaming engineers with technicians. However, it is not likely that automation will result in a proliferation of narrow technician groups (e.g., "robot technicians") for several reasons. Programing and other preparatory activities can occur relatively infrequently, while production processes and plants generally involve a variety of equipment, making dedicated applications planning or other support personnel unlikely in most cases.

Overall growth among the ranks of technicians does not preclude declines in individual categories. CAD, for example, will reduce demand for draftsmen, unless trends in product markets lead design activity to grow substantially.[41] Increases in productivity through CAD are generally measured as reductions in time relative to conventional drafting to perform a given task, particularly for detailing, revisions, or tests of designs (as distinct from

[40] Katherine Hafner, "Job Fair Shows Firms Not Seeking Entry-Level DPers, " *Computerworld*, May 23, 1983.

[41] Tupperware, for example, increased drafting employment after adopting CAD because the "department is able to produce more." See Joan Faulkner, "Computer-Assisted Drafting, " *The Providence Journal*, Oct. 16, 1983.

Table 22.—Combined Employment of Engineering Technicians, NC Tool Programers, and Computer Programers, 1980

	All industries		All manufacturing		Engineering, architectural, and surveying services		Metalworking machinery and equipment		Office computing and accounting machines		Electrical industrial apparatus		Electronic components and accessories		Motor vehicles and equipment		Aircraft and parts	
Engineering and scientific technicians	1,251,955	1.35%	439.852	2.16%	157,550	28.30%	0.303	2.77%	39.858	9.25%	10.107	4.24%	33.783	6.05%	9.182	1.19%	29.225	4.46%
Drafters	315,967	0.34	116.423	0.57	95,988	17.24	6.693	1.80	4.964	1.15	3.096	1.3	3.786	0.68	2.118	0.27	4.751	0.72
Electrical/electronic engineering	358.077	0.39	131.044	0.64	5.814	1.04	1.435	0.39	32.182	7.47	4.501	1.89	21.351	3.82	434	0.06	5.494	0.84
Industrial engineering	32.418	0.03	19,334	0.09	3,670	0.66	788	0.21	NA	NA	782	0.33	497	0.09	537	0.07	1.464	0.22
Mechanical engineering	48.452	0.05	40.775	0.20	2,269	0.41	583	0.16	1.877	0.44	748	0.31	1.796	0.32	2.413	0.31	8.920	1.36
Tool programers, NC	11,907	0.01	9.371	0.05	869	0.16	1.187	0.32	475	0.1	100	0.04	352	0.06	NA	NA	1.076	0.16
Computer programers	226.182	0.24	58.622	0.29	3.303	0.59	755	0.20	19.604	4.55	726	0.3	2.056	0.37	1.166	0.15	2.768	0.42

SOURCE: Bureau of Labor Statistics, "Employment by Industry and Occupation, 1980 and Projected 1990," unpublished data on wage and salary employment

design, per se). Fewer drafting hours, and presumably fewer drafters, are necessary to perform a given amount of work. Also, broader distribution of terminals and workstations, increased CAD/CAE system capabilities, and improved interactivity reduce the rationale for delegating drafting, programing, or data input to specialists. However, the tendency to train and use existing draftsmen in CAD operations is one reason why demand for them is likely to continue for quite some time.[42]

Also, anticipated improvements in equipment integration and interfaces will reduce the occasion for programing. For example, CAD/CAE stations are being developed that will automatically generate (and test) programs for robots or machine tools, and production equipment is being supplied with increasingly easy-to-use software, reducing the need for separate NC tool programmers or robot programmers. However, development of such systems is ongoing, and stand-alone NC equipment is likely to remain the norm throughout this decade.

As in the case of engineers, trends in industrial organization may also shape employment opportunities for technicians. First, the spread of programmable automation is expected to alter design interactions between prime manufacturers and their suppliers. Automobile and aerospace manufacturers, for example, are increasing computer-links with suppliers for transmission of design specifications. This trend could diminish drafter demand among suppliers. Second, CAD may influence companies' decisions on whether to do their own drafting or have it done on the out-

[42] OTA case studies: want-ads.

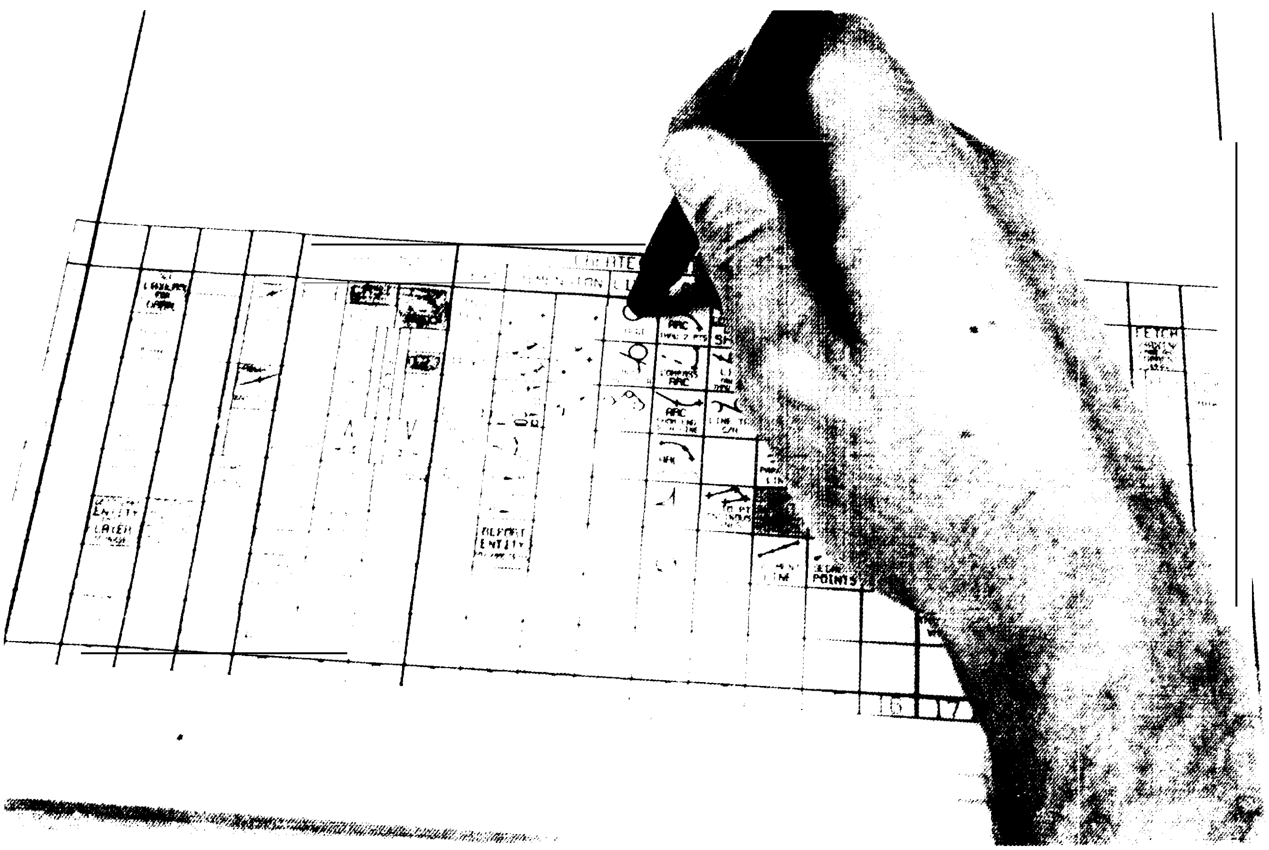

Photo credit Beloit Corp

Computer-aided design system "menu" for drafting, with light pen side. A shift to outside drafting, under the assumption that special service firms will be more efficient and productive in drafting activities, would further compress overall demand for draftsmen. Growth in the engineering services market for CAD systems suggests that demand for outside drafting, and perhaps some accompanying demand for outside technicians, may be strong. The manufacturing share of technicians fell between 1970 and 1978 largely because of a growth in the services share.[43] Trends in the 1970's reflect a rapid growth in product complexity and design requirements and the use of both manual and simple CAD systems; the continuation of these trends is thus uncertain.

In particular, manufacturers who have the potential to link CAD to production or other equipment may become less interested in buying outside drafting services as design becomes more important in their operations. One research center, for example, created a new job category, "CAD/CAM operator, " and hired technicians to work with CAD systems as an alternative to contracting with outside parties for drafting work.[44] Some manufacturers may use their own and outside personnel at the offices of new CAD service firms, which provide computer equipment time and technical support to companies unable to afford their own CAD facilities (see ch. 7).

SUPPLY AND UTILIZATION FACTORS

It is difficult to gauge whether the supply of technicians will be adequate, because persons can become technicians through many avenues that may or may not entail formal "technician training. As will be described in chapter 6, there is evidence that employers are beginning to prefer formal training for technicians, and to offer such training to prepare employees for programmable automation; in addition, independent, outside training is available to individuals to prepare for technician careers. Because their educational requirements are less (in terms of time, money, and rigor) than those of engineers and scientists, the supply of technicians can be increased much faster through appropriate training. This will tend to support proportionate growth in technicians as a class, although it is premature to forecast growth in specific categories.

Because programmable automation lowers the skill requirements for several engineering and production tasks, technicians can and do perform work that previously was considered either professional or skilled trade work. While this may always have taken place, PA is likely to make the substitution possibilities more obvious and numerous. The fact that growth of technician employment in manufacturing between 1977 and 1980 exceeded the growth rate for both scientists and engineers also suggests that technicians are being substituted for other types of personnel. Growing flexibility in staffing again suggests that conventional occupational descriptions and staffing conventions are of limited use for gauging future employment patterns.

Production and Related Workers

This broad category includes "all skilled, semiskilled, and unskilled workers performing machine and manual tasks involving production, maintenance, construction, repair, materials handling, and powerplant operations, " as defined by the Bureau of Labor Statistics (BLS). It contains the bulk of the occupations most directly vulnerable to displacement from programmable automation, as well as from past technological changes. Production workers have varied educational backgrounds and skill levels, but are less likely to have college training than are other occupational groups in manufacturing. They tend to acquire their skills on the job rather than through outside training.

[43] U.S. Department of Labor, Bureau of Labor Statistics, *The National Industry-Occupation Employment Matrix, 1970, 1978, and Projected 1990.* Bulletin 2086 (Washington, D. C.: U.S. Government Printing Office, April 1981). Almost 53 percent of engineering and science technicians were employed in manufacturing in 1970; almost 48 percent were in 1978. During that period, the proportion employed in services rose from over 20 percent to almost 24 percent.

[44] OTA case study.

OVERALL EMPLOYMENT TRENDS

Production and related workers are, overall, the largest occupational group in manufacturing industry employment, with about 14 million employees in 1980. This group's share of manufacturing employment has been declining. In 1980, 68.1 percent of manufacturing employees were production and related workers, compared with 70.8 percent in 1977. This group constitutes the largest proportion of workers in all industries surveyed by BLS in its Occupational Employment Survey (OES) of manufacturing industries. According to 1980 OES data, the highest absolute numbers of these workers are found in the machinery (1.52 million), electrical and electronic equipment (1.25 million), and transportation equipment (1.19 million) industries-the three broad industry groups in which PA is produced and most heavily used.

The group as a whole contains three principal classes of workers, by descending order of skill: craft and related workers, operatives, and laborers. In 1980, there were 3,768,395 craft and related workers, accounting for 18.51 percent of manufacturing employment. This group included 695,157 (3.4 percent of manufacturing employment) mechanics, repairers, and installers; 668,002 (3.3 percent) metalworking craftworkers (excluding mechanics); and 1,751,529 (8.6 percent) others (e.g., welders, painters, etc.). Table 23 details some of the occupations within these categories. In addition, there were 8,845,318 (43.4 percent) operatives. This group included 1,661,150 (8.2 percent) assemblers; 1,470,169 (7.2 percent) metalworking operatives, and 5,713,999 (28.1 percent) other operatives. Finally, there were 1,576,576 (7.7 percent) laborers. Some of the occupations within these categories are listed in table 24. Note that, between 1972 and 1980, production worker employment grew slowly across the economy, with employment among craftworkers growing the most, followed by laborer employment, and with no growth among operatives.[46]

[46]Carol Boyd Leon, "Occupational Winners and Losers: Who They Were During 1972 -1980," *Monthly Labor Review,* June 1982.

A critical question for future employment levels among production occupations is whether and how much the total amount of domestic production changes; technologies that lower labor input for a given amount of output do not alone lower employment levels. For example, companies using more (or more expensive) equipment because of PA may find operating for more hours in the day more profitable. Adding one or more production shifts is possible if the companies can sell the extra output; it also can increase or sustain company employment. On the other hand, if demand does not support growth in industry output, employment may merely be shifted among firms.

It is important to remember that factors other than automation are motivating declines in production employment among metalworking industries: reductions in the amount and proportion of metal used in a variety of products, and increases in the use of such other materials as plastics and ceramics will reduce employment of metal craftworkers.* However, where the materials shift occurs within a given firm, metalworking employees may move to work with other materials, keeping their jobs but changing their labels. Recent increases in offshore production also depressed domestic employment in metalworking industries, particularly for production and related workers. For example, U.S. auto companies have established component plants offshore, and U.S. aerospace firms have entered into coproduction or other supply agreements with firms located abroad. Increases in imports have a similar effect. Table 25 presents employment in industries particularly affected by foreign trade. As noted above, the growth in foreign sourcing of parts and other products is attributable in part to lower labor costs overseas, although differences in accounting make precise comparisons difficult.

*Materials changes also may affect skill requirements. For example, less skilled workers are needed to install plastic piping than metal piping. Within the miscellaneous plastics products industry, craft and related workers comprised 16 percent of 1980 employment, while operatives comprised 56 percent. See James D. York, "Productivity Growth in Plastics Lower Than All Manufacturing, " *Monthly Labor Review,* September 1983.

Table 23.—Craftworker Employment and Selected Occupations, 1980
(All manufacturing industries, wage and salary workers)

Occupation	Number	Percent
Craft and related workers	3,768,395	18.51
Construction craftworkers	296,458	1.46
Electricians	126,001	0.62
Plumbers and pipefitters	61,747	0.30
Mechanics, repairers, and installers	695,157	3.41
Air-conditioning, heating, and refrigeration mechanics	11,759	0.06
Aircraft mechanics	19,603	0.10
Automotive mechanics	51,867	025
Data-processing machine mechanics	18,050	0.09
Diesel mechanics	3,316	0.02
Electrical instrument and tool repairers	2,979	0.01
Electric motor repairers	1,578	0.01
Engineering equipment mechanics	11,056	0.05
Instrument repairers	22,537	0.11
Knitting machine fixers	10,578	0.05
Loom fixers	17,877	0.09
Maintenance mechanics	209,673	1.03
Maintenance repairers, general utility	181,851	0.89
Millwrights	68,926	0.34
Office machine and cash register servicers	1,864	0,01
Radio and television repairers	5,136	0.03
Section repairers and setters	13,553	0.07
Sewing machine mechanics	12,141	0.06
Metalworking craftworkers, except mechanics	668,002	3.28
Boilermakers	11,966	0.06
Coremakers, hand, bench, and floor	9,107	0.04
Forging press operators	8,727	0.04
Header operators	5,385	0.03
Heat treaters, annealers, and temperers	24,866	0.12
Layout markers, metal	20,664	0.10
Machine tool setters, metalworking	55,312	0.27
Machinists	197,849	0.97
Molders, metal	38,807	0.19
Patternmakers, metal	7,336	0.04
Punch press setters, metal	19,141	0.09
Rolling mill operators and helpers	10,708	0.05
Shear and slitter setters	5,462	0.03
Sheet-metal workers and tinsmiths	80,729	0.40
Tool-and-die makers	158,586	0,78
Printing trades craftworkers	357,249	1,75
Bookbinders, hand and machine	22,674	0.11
Bindery machine setters	6,453	0.03
Compositors and typesetters	105,465	0.52
Etchers and engravers	11,964	0.06
Photoengravers and lithographers	52,601	0.26
Press and plate printers	156,242	0.77
Other craft and related workers	1,751,529	8.61
Blue-collar worker supervisors	705,307	3.46
Cabinetmakers	28,020	0.14
Crane, derrick, and hoist operators	68,589	0.34
Food shapers, hand	4,431	0.02
Furniture finishers	5,756	0.03
Heavy equipment operators	17,052	0.08
Inspectors	433,530	2,13
Jewelers and silversmiths	4,373	0.02
Lens grinders	8,057	0.04
Log inspectors, graders, and scalers	4,701	0.02
Logging tractor operators	13,380	0.07
Lumber graders	5,614	0.03
Machine setters, paper goods	9,955	0.05
Machine setters, plastic materials	7,415	0.04

Table 23.—Craftworker Employment and Selected Occupations, 1980 (All manufacturing industries, wage and salary workers) —Continued

Occupation	Number	Percent
Machine setters, woodworking	5,121	0.03
Millers	6,204	0.03
Patternmakers, wood	6,716	0.03
Patternmakers, n.e.c.	1,374	0.01
Shipfitters	14,389	0.07
Stationary engineers	17,684	0.09
Tailors	8,107	0.04
Testers	104,745	0.51
Upholsterers	20,562	0.10
Upholstery cutters	6,802	0.03
Upholstery workers, n.e.c.	15,495	0.08
Veneer graders	5,055	0.02

n e c - Not elsewhere classified

SOURCE Bureau of Labor Statistics, 'Employment by Industry and Occupation, 1980 and projected 1990 Alternatives un published dataon wage and salary employment

MECHANICS, REPAIRERS, AND INSTALLERS

The spread of programmable automation will increase the proportion and the role of mechanics, repairers and installers (MRI) in manufacturing because it will increase rates of installation and levels of use of equipment, and because both the risk and cost of production stoppage due to equipment malfunction will grow as production becomes more capital-intensive. Though the reliability of individual pieces of equipment appears to be increasing, isolated problems often affect whole systems where equipment is integrated. As manufacturers come to depend more on equipment, their need to be able to respond quickly to problems will grow. In many cases, that need will be met by "throwing people at the problem," although the need to do so may decline as people learn how to develop still better systerns. Between 1972 and 1980, data-processing machine repairers experienced one of the largest percentage employment increases among all occupations; employment in this occupation grew 89.4 percent compared to an average rate of 19.1 percent. Note, however, that individual MRI occupations account for very small proportions of industry employment (under 2 percent each). Table 26 shows MRI employment levels for 1980 across manufacturing industries.

Programmable automation will also have a major impact on the types of skills required of mechanics, repairers, and installers. Improvements in diagnostic technologies and the growing tendency to replace rather than repair electronic components have lowered the skill requirements for many specific diagnostic or repair tasks (less skill depth). * On the other hand (as was mentioned earlier), the combination of mechanical, electrical, and electronic features that characterizes programmable automation makes skill breadth necessary for repair and maintenance operations. These operations are likely to involve more, and more varied, tasks than are encountered in repair and maintenance of conventional equipment. In some cases, individuals need broader skills than before because maintenance of automated equipment has been added to other maintenance work while the number of personnel has been kept constant. While individuals may need broader skills, in larger firms repair and maintenance personnel may be deployed in teams of persons with different or overlap-

*For example, DEC has been developing the "Intelligent Diagnostic Tool" to enable field service personnel to diagnose equipment problems described by customers over the phone. The IDT is based on an expert system. See Martyn Chase, "DEC Says Artificial Intelligence Enabled It To Save $10 Million, " *American Metal Market/Metalworking News,* Apr. 4, 1983.

Table 24.—Operative and Laborer Employment and Selected Occupations, 1980
(All manufacturing industries, wage and salary workers)

Occupation	Number	Percent
Operatives	8,845,318	43.44
Assemblers	1,661 ,150	8.16
Aircraft structure and surfaces assemblers	25,353	0.12
Clock and watch assemblers	4,362	0.02
Electrical and electronic assemblers	232,694	1.14
Electromechanical equipment assemblers	58,174	0.29
Instrument makers and assemblers	24,681	0.29
Machine assemblers	101,043	0.50
All other assemblers	1,214,843	5,97
Bindery operatives	77,918	0.38
Laundry, drycleaning, and pressing machine operatives	57,132	0.28
Meatcutters and butchers	64,015	0,31
Metalworking operatives	1,470,169	7.22
Dip platers, nonelectrolytic	12,768	0.06
Drill press and boring machine operators	124,232	0.61
Electroplates	36,013	0.18
Furnace chargers	5,520	0.03
Furnace operators, cupola tenders	16,814	0.08
Grinding and abrading machine operators, metal	128,053	0.63
Heaters, metal	6,473	0.03
Lathe machine operators, metal	155,935	0.77
Machine-tool operators, combination	167,942	0.82
Machine-tool operators, numerical control	52,627	0.26
Machine-tool operators, tool-room	38,352	0.19
Milling and planing machine operators	72,061	0.35
Pourers, metal	15,311	0.08
Power brake and bending machine operators, metal	39,877	0.20
Punch press operators, metal	182,364	0.90
Welders and flamecutters	400,629	1,97
All other metalworking operatives	15,198	0.07
Mine operatives, n.e.c.	9,951	0.05
Packing and inspecting operatives	587,631	2,89
Painters, manufactured articles	117,289	0.58
Decorators, hand	4,748	0.02
Rubbers	6,363	0.03
Painters, production	106,178	0.52
Sawyers	76,728	0.38
Sewers and stitchers	845,294	4.15
Textile operatives	378,540	1.86
Transportation equipment operatives	711,195	3.49
Industrial truck operators	269,105	1.32
All other operatives	2,788,306	13.69
Batch plant operators	7,369	0.04
Boring machine operators, wood	4,184	0.02
Coil finishers	7,422	0.04
Cutters, machine	28,048	0.14
Cutters, portable machine	16,472	0.08
Cutter-finisher operators, rubber goods	7,184	0.04
Cutting machine operators, food	11,692	0.06
Die cutters and clicking machine operators	19,680	0.10
Filers, grinders, buffers, and chippers	115,680	0.57
Furnace operators and tenders, except metal	29,378	0.14
Mixing operatives	48,337	0.24
Nailing machine operators	9,352	0.05
Oilers	22,657	0.11
Photographic process workers	12,439	0.06
Power screwdriver operators	8,515	0.04
Punch and stamping press operators, except metal	5,284	0.03
Riveters	14,161	0.07
Sandblasters and shotblasters	10,440	0.05
Sanders, wood	20,684	0.10

Table 24.—Operative and Laborer Employment and Selected Occupations, 1980 (All manufacturing industries, wage and salary workers) —Continued

Occupation	Number	Percent
Shaper and router operators	4,655	0.02
Shear and slitter operators, metal	30,380	0.15
Shoemaking machine operators	64,568	0.32
Winding operatives, n.e.c.	49,157	0.24
Wirers, electronic	30,611	0.15
Laborers, except farm	1,576,576	7.74
Cannery workers	75,066	0.37
Conveyor operators and tenders	31,469	0.15
Furnace operators and heater helpers	8,316	0.04
Helpers, trades	100,752	0.49
Loaders, cars and trucks	5,941	0.03
Loaders, tank cars and trucks	5,579	0.03
Off-bearers	22,499	0.11
Riggers	16,211	0.08
Setters and drawers	7,157	0.04
Shakeout workers, foundry	10,580	0.05
Stock handlers	104,208	0.51
Order fillers	104,208	0.51
Timbercutting and logging workers	36,104	0.18
Work distributors	16,895	0.08
Laborers, except farm, n.e.c.	1,104,071	5.42

n e c = Not elsewhere classified.

SOURCE Bureauof Labor Statistics. "Employment by Industry and Occupation, 19S0 and projected 1990 Alternatives," unpublished dataon wage and salary employment

ping skills, although this may result from work rules established by labor contracts as well as the changing demands of technology.

The potential for long-term growth in absolute numbers of mechanics, repairers, and installers is uncertain. Several factors will limit that growth. First, where small, stand-alone systems are used, vendors or existing maintenance personnel are likely to repair the new equipment. For example, a producer of shoemanufacturing machinery who installed a single welding robot in an old facility simply trained its existing electrician to repair the robot.* Where installations involve a lot of equipment, especially if integrated, new maintenance personnel may be added. One automobile manufacturer, for example, took on several new repair personnel to service an automated welding system.[40]

The fact that more hardware maybe used for a given amount of manufacturing implies that more maintenance personnel will be needed, but experience suggests that for each user there is a threshold level of new equipment that must be attained before new personnel are hired. That level varies substantially among companies and industries. Also, automation of diagnostic and repair procedures reduces the amount of diagnosis and repair work. These developments, and related trends such as growth in service hot-lines and equipment communications links, will dampen the potential growth in maintenance personnel. Finally, computerization generally carries with it new needs for maintenance of software, although this work has typically been done by people classified as "data-processing professionals, rather than production workers.

One development in particular that may curb employment growth for mechanics, repairers, and installers is equipment and system insurance. Companies may choose to insure against the loss (of equipment and/or profit) associated with a breakdown as an alternative to protecting against that loss by employing a lot of machinists or repairmen. There is evidence that some companies have been making such a choice while using conventional equipment; the number of losses re-

*OTA site visit.

[40]OTA case study.

Table 25.—Trade-Sensitive Employment

Input-Output class[a]	Industry description	Net trade-related job opportunities 1964	Net trade-related job opportunities 1975	Change in net trade-related job opportunities between 1964 and 1975: Total	Direct	Indirect
The 20 industries in which job opportunities were most adversely affected by trade between 1964 and 1975						
1804	Apparel, purchased	-41,569	-144,932	-103,363	-87,048	-16,315
5903	Motor vehicles and parts	12,256	-63.939	-76.195	-54,299	-21,896
3701	Furnaces, steel products	10.055	-36,447	-46.502	-32,825	-13,677
3402	Non rubber footwear.	-8,570	-46,315	-37,745	-36,790	-957
6105	Motorcycles, bicycles, and parts	-7,150	-29,817	-22,667	-19,980	-2,687
5601	Radio and television sets	-5,581	-25,986	-20,405	-19,098	-1,307
1601	Broad woven fabric mills	-22,688	-40.815	-18,127	7.810	-25.937
3202	Rubber footwear.	-4,601	-15,292	-10,691	-10,377	-314
3101	Petroleum refining	-2,190	-12,395	-10,205	-9,843	-362
2307	Furniture and fixtures, nec	-3,101	-13,094	-9,993	-9,933	-66
5104	Office machines, nec	-700	-9.235	-8,535	-8,329	-206
3403	Other leather products	-7,337	-15,647	-8.310	-7,898	-412
5701	Electron tubes	359	-7,443	-7.802	1,022	-8>824
1802	Knit apparel mills	-3,186	-9,946	-6.760	0	-6.760
2801	Plastic materials and resins	9,923	3,531	-6,392	-5,493	-899
4802	Textile machinery	4,325	-1,805	-6,130	-5,519	-611
1903	Fabricated textiles, n.e.c	4,149	-1,714	-5,863	-1,709	-4,154
4701	Machine tools. metal cutting types	9,388	3.558	-5,830	-6.161	331
2201	Wood household furniture	-96	-5,242	-5.146	1,324	-6,470
3201	Tires and inner tubes	1,722	-3,357	-5,079	-3,882	-1.197
The 20 industries in which job opportunities were most favorably affected by trade between 1964 and 1975						
6001	Aircraft	22,633	76.683	54,050	48.104	6,036
6004	Aircraft equipment, nec	33,246	78,542	45,296	19,507	25,789
5101	Computing machines	16,183	54,666	38,483	32.544	5,939
2001	Logging	-17.967	8,278	26,245	13,785	12,460
4503	01 I field machinery	6,410	26,915	20,505	19,313	1,192
4501	Construct Ion machinery	30,094	47,720	17,626	16,267	1,359
5301	Electric measuring instruments	4.897	17,671	12.774	11,671	1,103
2002	Sawmills and planing mills	-31,566	-19,372	12,194	10,021	2,173
6002	Aircraft engines and parts	15.769	26,201	10.432	3.812	6.618
2402	Paper mills	-23,444	-13,154	10,290	9.518	772
4806	Special Industrial machines	11,738	21,392	9.654	9.134	520
4901	Pumps and compressors	7,711	17,006	9,295	7,598	1,697
5304	Motors and generators	9,244	16.473	7.229	5,267	1,962
5503	Wiring devices	4,351	11,458	7,107	4.440	2,667
5703	Electronic components	15,371	21,990	6.619	5,138	1,481
5702	Semiconductors	4.984	11,182	6,198	4,961	1.237
2006	Veneer and plywood	-13.734	-7,669	6,065	4.806	1,259
4006	Fabricated plate work	6,664	11,926	5,262	4,401	861
5203	Refrigerator machines	5,932	11,120	5,188	6,154	-966
5000	Machine shop products	12,128	17,204	5,076	1,612	3,464

[a]The concordance between I-O (input-output table) classifications and standard industrial classifications is published in *Survey of Current Business* February 1974

n.e.c. Not elsewhere classified

SOURCE: G. Gregory, K. Schott, file: Imports and Domestic Employment Identifying Affected Industries, *Monthly Labor Review* August 1982

corded by insurers that are attributed to inadequate maintenance is growing. Historically, U.S. casualty and property insurers have refused to insure computers and computerized equipment. However, Kemper has recently decided to cover such equipment under its boiler and machinery program, and other insurance companies are expected to follow suit.[47] Meanwhile, the American press has treated the offering of "robot insurance" in Japan as an oddity.

[47]Bob Nielsen, Kemper Insurance, personal communication, November 1983.

OTHER CATEGORIES

The remaining categories of production and related workers—metalworking and other craftworkers, operatives, and laborers—are to varying degrees likely to experience displacement due to programmable automation, other

Table 26.—Employment of Mechanics and Related Personnel, 1980

	All manufacturing		Metalworking machinery and equipment		Office computing and accounting machines		Electrical industrial apparatus		Electronic components and accessories		Motor vehicles and equipment		Aircraft and parts	
MRI[a] and construction craftworkers	991,615	4.90/.	7,292	2.00/0	19,097	4.40/0	8,666	3.6°/0	14,976	2.70/o	44,497	5.8%	40,190	6.1%
Electricians	126,001	0.6%	1,955	0.5%	813	0.2%					1,451	0.6%	1,762	0.3%
Data-processing machine mechanics	18,050	0.09%	NA		14,296	3.32%					191	0.08%	312	0.06%
Instrument repairers	22,537	0.1%	NA	NA	NA	NA					172	0.07%	285	0.05%
Maintenance repairers, general utility	181,851	0.9%	1,642	0.4%	1,528	0.4%					1,552	0.7%	4,378	0.8%
Electric motor repairer	1,578	0.01%	—		—						1,073	0.5%	151	0.03%
Electrical instrument tool repairer	2,979	0.01%	—		—						134	0.06%	1,326	0.24%

[a]MRI = Mechanics, repairers, and installers.
NA = Not available.
NOTE: Percentages have been rounded.

SOURCE: Bureau of Labor Statistics, "Employment by Industry and Occupation, 1980 and Projected 1990," unpublished data on wage and salary employment

things being equal. This group, which dominates manufacturing employment, numbered over 12 million in 1980.

There are no simple rules about how automation displaces production workers; however, it is clear that as long as production volume is constant and automation improves productivity (or as long as volume grows significantly less than productivity), it will displace production jobs. By design, such innovations as automated controls, the use of robots and other manipulators to load and unload machines, flexible fixtures (which are replaced or adjusted less often than conventional ones), the linking of automated production and materials handling equipment into systems, and the use of computers to regulate the flow of materials and work-in-process will: 1) reduce the amount and type of human activity required in any given operation, and 2) decrease the number of workers required to perform a given amount of work. Robots, for example, are currently not faster than people for most applications, but they may be more consistent, performing with fewer errors over time and taking less time to achieve a given level of quality.

In practice, the potential for displacement will vary enormously by application and facility. For some applications, one "operator" may be needed at one machine; for others, one person may tend several machines. In many cases, the linking of activities by automated materials handling (robotic or other) will reduce the labor component for setup; both trends will increase the machine-to-person ratio.

Throughout this decade, technological limitations (particularly in the areas of sensors and interfaces) are likely to restrict the tasks in which PA may be used, and economic considerations will continue to moderate the rate of diffusion and the extent to which products and processes are redesigned. Looking toward the future, no case-by-case evaluation of occupations can convey the potential for displacement implied by the integration of manufacturing equipment and systems because it cannot capture all of the indirect impacts on staffing. Experience with highly integrated systems is quite limited, and it shows that initial applications using current technology require more labor than had been anticipated. The employment effects of highly integrated systems are not likely to be significant until at least the 1990's, and even then are likely to remain concentrated in the machinery and transportation equipment industries.

The problems in gauging displacement from PA overall can be illustrated by examining the cases of welders and flamecutters, painters, and machinists. Welders and flamecutters numbered 400,629 (1.97 percent of manufacturing employment) in 1980, and production painters numbered 106,178 (0.52 percent). Table 27 shows their distribution across selected metalworking industries. While automatic welding machines have been available for some time, interest in using robots for welding and spray painting was a major factor in the commercialization of robot technology. A principal motivation for these robot applications, in addition to the prospect of lower labor costs,

Table 27.—Distribution of Flamecutters, Welders, and Production Painters in the Metalworking Industries, 1980

	Welders and flamecutters		Production painters	
	Number	Percent	Number	Percent
All manufacturing	400,629	2.0 "/0	106,178	0.50/0
Metalworking machinery and equipment	6,562	1.8	1,284	0.4
Office, computing, and accounting machines	2,094	0.5	1,172	0.3
Electrical industrial apparatus	3,872	1.6	1,195	0.5
Electronic components and accessories	2,405	0.4	1,229	0.2
Motor vehicles and equipment	41,159	5.3	13,556	1.8
Aircraft and parts	6,193	0.9	4,295	0.7

NOTE Percentages have been rounded.

SOURCE Bureau of Labor Statistics, "Employment by Industry and Occupation, 1980 and Projected 1990, " unpublished data on wage and salary employment

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was the elimination of particularly unpleasant and hazardous work.

It is easier to gauge displacement potential for these occupations than for others because the source of displacement appears limited to a single automation technology, robots. However, all welders and production painters are not alike. Those whose work is most monotonous and unpleasant are most likely to be displaced, other things being equal; that category includes spot welders and spray painters in the auto industry. By contrast, it is less applicable to welders in the aircraft industry, who are more likely to do arc welding. Although sensor and machine vision advances will make arc welding increasingly susceptible to automation during this decade, it is not clear whether automated welding will ever be of sufficiently high quality to displace large proportions of these workers. Also, because much arc welding is not done in a mass-production context (like automotive spot welding), human performance may be more economical in many cases.

Even with automation of welding and painting, human input is still required for setup, supervision, inspection, adjustment, and/or retouching, because of the shortcomings of auto mated equipment. Painting is easier to automate than welding because it is easier to control the quality of the work. Improvement in automated inspection systems is likely to reduce, but not eliminate, the labor component needed for supervision, inspection, adjustment —and therefore retouching-by the 1990's. The Upjohn Institute robotics study concluded that 15 to 20 percent of welding jobs and 27 to 37 percent of painting jobs in the auto industry (3 to 6 percent and 7 to 12 percent, respectively, for jobs in all other manufacturing industries) could be displaced by robots by 1990; Ayres and Miller estimated that between about 93,000 and 169,000 welders and between about 35,000 and 52,000 painters could eventually be displaced by robots, depending on the level of sophistication.[48]

The displacement potential for machinists is much less clear-cut. There were 197,849 machinists (0.97 percent of manufacturing) employed in manufacturing in 1980, according to OES. BLS recently addressed the question of machinist employment, drawing on Current Population Survey (CPS) as the richest data source for this purpose.[49] According to the CPS, which also provides detailed data on other skilled and operative machining occupations, there were 567,000 machinists in 1980; there were 834,000 total skilled machine workers, including machinists, job and die setters, and tool and die makers.

While NC machining can do some tasks that are beyond the capabilities of people working with conventional machine tools, a principal motivation in the development and spread of NC equipment has been alleged shortages of machinists, who are highly skilled, well-paid craftsmen. Between 1972 and 1980, CPS data show that machinist employment rose by 190,000, while employment in other skilled machining occupations fell. For purposes of comparison with other occupational statistics presented in this chapter, table 28 presents machinist employment levels in several metalworking industries according to OES data.

The proportion (and number) of skilled machinists is likely to fall in the long term because of growing use of NC technology, especially among smaller firms, and because of constraints on supply. This will happen because in some cases NC allows less skilled people to substitute for skilled journeyman machinists in operating and/or progr aming machine tools.

> One major response from management to the skills shortage has been to de-skill the work the journeyman once handled himself. In effect, one job is broken down into its various elements and then distributed among workers who are able to learn these smaller tasks.[50]

Meanwhile, entry into skilled machinist jobs is limited by the need for a lengthy skill-acquisition process (apprenticeships, for exam-

[48] Hunt and Hunt, op. cit.; and Robert U. Ayres and Steven Miller, "Robotics, CAM, and Industrial Productivity, " *National Productivity Review*, winter 1981-1982.

[49] Neal H. Rosenthal, "Shortages of Machinists: An Evaluation of the Information, " *Monthly Labor Review*, July 1982.

[50] Daniel D. Cook and John S. McClenahen, "Skilled Worker Nears Extinction, " *Industry Week*, Aug. 29, 1977.

Table 28.—Machinist Employment, 1980

	Machinists		Machine toolsetters, metalworking		Tool and die makers	
	Number	Percent	Number	Percent	Number	Percent
All manufacturing	197,849	1,0	55,312	0.3	158,586	0.8
Metalworking machinery and equipment	19,181	5.2	3,112	0.8	42,356	11.4
Office, computing, and accounting machines	1,987	0.5	1,063	0.3	1,849	0.4
Electrical industrial apparatus	2,701	1.1	1,630	0.7	2,638	1.1
Electronic components and accessories	4,108	0.7	708	0.1	3,599	0.6
Motor vehicles and accessories	2,468	0,3	9,993	1.3	11,811	1.5
Aircraft and parts	7,251	1.1	4,738	0.7	6,214	1.0

NOTE Percentages have been rounded

SOURCE Bureau of Labor Statistics Employment by Industry and Occupation, 1980 and Projected 1990, " unpublished data on wage and salary employment

pie, usually last 4 years). * Consequently, although the need for highly trained machinists varies among firms and industries, it is likely that the overall level of metalworking skills will drop because machinists are among the most skilled of metalworking craftsmen.

At least in the short term, however, increases in defense expenditures will certainly lead to shortages of machinists-which will in turn spur the introduction of NC. A recent study performed by Data Resources, Inc., for the U.S. Department of Defense, forecasts shortages of machinists and other metalworking personnel by 1987. It concludes that defense expenditures will account for almost 60 percent of the growth in machinist demand between 1981 and 1987 (compared to a defense share of 120 percent for assembler-demand growth and 87 percent of metalworking operative demand growth) .51 While that study does not appear to account for metalworking technology changes, and may therefore overstate the potential for shortages, it underscores the importance of production volume as a major influence in employment opportunities. One reason behind the belief in a machinist shortage is the cyclical nature of machinist demand; the unevenness in metalworking product demand, especially that which is associated with defense spending, tends to place employers in a hiring position when demand surges.

Two groups of relatively low-skilled production workers, materials handlers and assemblers, may be quite vulnerable to displacement in the long run. Various forms of automated materials handling, robots, and automated storage and retrieval systems (AS/RS) can substitute for such materials handlers as conveyor operators; crane, derrick, and hoist operators; and industrial truck operators. Manufacturing employment in these categories totaled 370,000 in 1980. For example, central control computers for automatic guided vehicle systems can monitor location, load, and obstacles, and issue commands to vehicles in response to problems. PA can also replace people who manually load, unload, and transfer materials. For example, in plastics processing, robots perform such tasks as lifting, tilting, twisting, positioning, aligning, and transferring items; loading and unloading machines; and handling and orienting finished parts. Materials handling employment will also be affected by procedural changes, such as adoption of "just-in-time' delivery of supplies; the use of manufacturing resources planning (MRP) and other systems to rationalize the flow and use of materials; and other measures to reduce inventories.

The biggest changes in materials handler employment, at least in the near term, will come in large establishments. Large firms and

*Surveys show that industry efforts to increase machinist supply have been limited. According to one: "In some areas, it apparently is not a scarcity of journeymen but the price tag they bear—and industry's willingness to meet it—which effectively results in a skills shortage. " See Daniel D. Cook and John S. McClenahen, "Skilled Worker Nears Extinction. " *Industry Week*, Aug. 29, 1977, and "Attitudes Toward the Skilled Trades: Employment Issues in the Precision Metalworking Industry, report of a survey conducted for Sentry Insurance on behalf of the Task Force on the Skilled Trades Shortage by Louis Harris and Associates, Inc., November 1982.

"Ralph M. Doggett, "Regional Forecasts of Industrial Base Manpower Demand, 1981 to 1987, " prepared for the Office of the Under Secretary of Defense for Research and Engineering by Data Resources, Inc., March 1983.

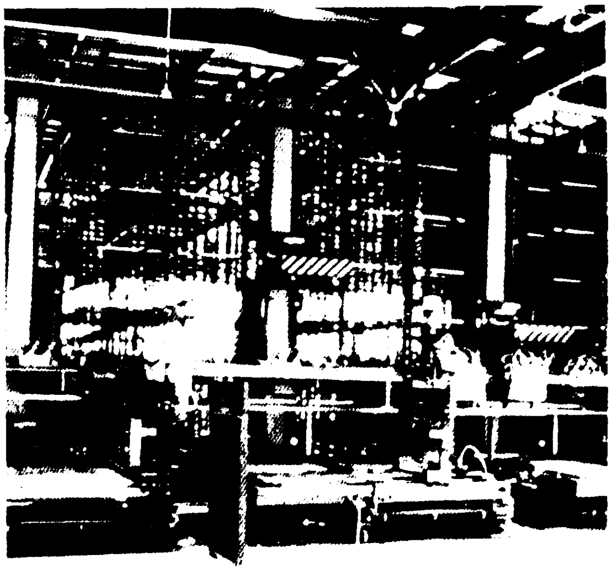


Photo credit' Cincinnati Milacron, Inc.

Automated materials handling, storage, and retrieval, with automated guided vehicles

plants are more able and likely to install AS/RS, can most easily implement MRP, and are more likely to link automated materials handling to production activities.* Materials handling robot applications are more practical for a wide range of firm sizes and industries, but are relatively limited at present (see ch. 3). Also, even where production is highly automated, labor is used for the initial input and/or final removal of materials from the system or the transfer from one stage to another. In contemplating flexible manufacturing systems, for example, it can be misleading to look only at the automated operations instead of the entire production process.

Assemblers perform tasks that range from the insertion of electronic components into circuit boards to building aircraft. In 1980, there were 1,661,150 (8.16 percent of manufacturing) assemblers in manufacturing. Table 29 shows their distribution across selected metalworking industries. The degree of complexity and margin for error of specific assembly tasks govern their ease of automation. Sensor and machine vision technologies can improve the precision and consistency of automated assembly equipment, and assembly applications of robots are expected to grow by the end of this decade. For example, the Upjohn Institute estimated that robots could displace 1 to 3 percent of assemblers by 1990 (including 5 to 10 percent of auto-industry assemblers); Ayres and Miller estimated that robots could ultimately displace between about 132,000 and 396,000 assemblers, depending on technological sophistication, in metalworking industries.[52]

The vulnerability of assemblers to displacement varies substantially by product type. For example, with miniaturization many electronics products cannot be assembled (or inspected) adequately by people. Also, many electronics products must be assembled in sterile environments where managers aim to minimize all sources of contaminants, including those naturally conveyed by people. In these cases, special equipment, not necessarily programmable, may be designed to do assembly and inspection work. Improvements in

*One gauge of potential changes in materials handling (especially for larger facilities) is the experience of food warehousers, many of which have implemented AS/RS. For example, B. Green & Co., a Baltimore full-line food wholesaler, hoped to triple its business by opening a new $22 million semi-automated warehouse and consolidating activities presently conducted at several locations. The company expected to lay off about 60 workers, most of them part-time. See Joyce Price, "60 Workers Lose Out to Automation," *The News Amen-can,* March 1983.

'*Hunt and Hunt, op. cit.; and Ayres and Miller, op. cit.

Table 29.-Employment of Assemblers in Selected Manufacturing Industries, 1980

	Number	Percent
All industries	1,661,201	1.8%
All manufacturing	1,661,150	8.2
Metalworking machinery and equipment	24,779	6.7
Office, computing, and accounting machines	85,714	19.9
Electrical industrial apparatus	50,987	21.4
Electronic components and accessories	169,759	30.4
Motor vehicles and equipment	175,922	22.7
Aircraft and parts	64,126	9.8

NOTE: Percentages have been rounded.

SOURCE: Bureau of Labor Statistics, "Employment by Industry and Occupation, 1980 and Projected 1990," unpublished data on wage and salary employment

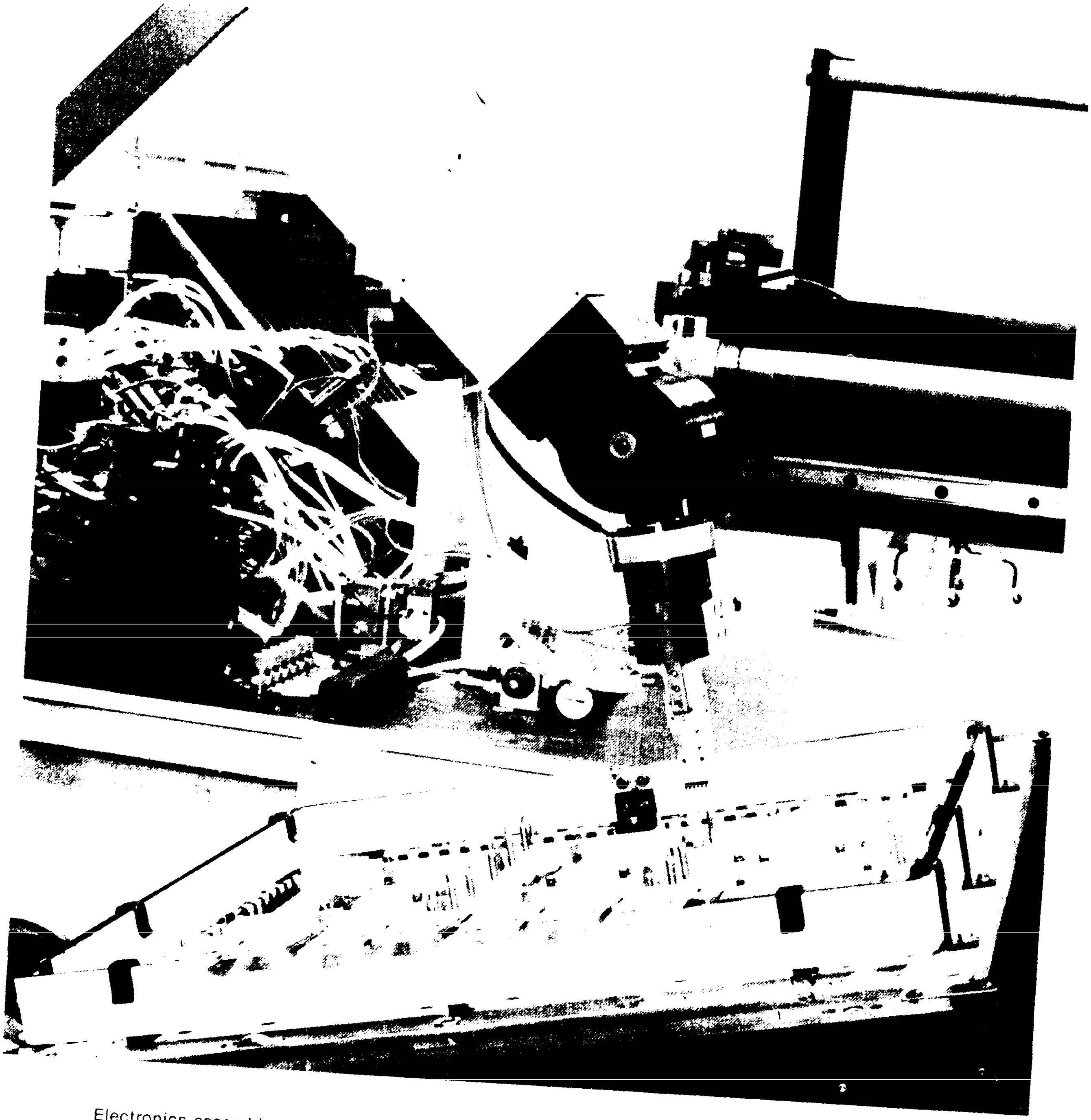


Photo credit: IBM Corp.

Electronics assembly application: Close-up of robot arm with small resistor pack ready for insertion in printed circuit board socket product design, often associated with the adoption of PA, will also reduce the amount of (or at least simplify) assembly work needed in manufacturing. For example, GE invested $38 million in a highly automated dishwasher factory and redesigned the products, reducing the number of different parts handled from 4,000 to 800.[59]

Note that inspectors may be affected by similar developments as assemblers, including improvements in sensor technology. In 1980 there were 433,530 manufacturing inspectors (2.13 percent of manufacturing). Table 30 shows the distribution of inspectors in selected metalworking industries. Many observers believe that the role and number of inspectors and other quality-control personnel will diminish as companies move from end-of-the-line quality-control inspection to in-line quality assurance. This will often happen as a consequence or corollary of automating. At least one company, for example, offers statistical process-control software in conjunction with its line of robots. General Motors, for example, expects that a combination of statistical process control, just-in-time supply scheduling, and other measures will substantially reduce the amount of receiving work in its new "Buick City" complex.[54]

[53]Bruce Vernyi, "Automated Dishwasher Plant Opens, " *American Metal Market/Metalworking News,* May *2, 1983.*
[54]Al Wrigley, "GM Awards Buick City Contract to Progressive, " *American Metal/Metalworking News,* Aug. 15, 1983.

Table 30.–Employment of Inspectors, 1980

	Number	Percent
All industries	471,984	0.50/0
All manufacturing	433,530	2.1
Metalworking machinery and equipment	5,781	1.6
Office, computing, and accounting machinery	12,991	3.0
Electrical industrial apparatus	6,744	2.8
Electronic components and accessories	22,072	4,0
Motor vehicles and equipment	38,769	5.0
Aircraft and parts	28,914	4.4

NOTE: Percentages have been rounded

SOURCE Bureau of Labor Statistics, "Employment by Industry and Occupation, 1980 and Projected 1990, " unpublished data on wage and salary employment

Finally, some new production jobs may emerge as an indirect result of changes in production processes and/or organizational procedures associated with PA. For example, when an auto manufacturer introduced a multi-robot spot-welding system, it began to produce major auto-body parts with corresponding notches and tabs which are connected prior to automated welding by an individual on the line; this new job is called "toy-tabbing." At an aircraft manufacturer, the introduction of an automated monitoring system for an automated machine shop was accompanied by the introduction of relief operators, a group of individuals who substitute temporarily for full-time staff.[55] In some cases, these new jobs may be transient, reflecting the requirements of a given level of automation, while in other cases they may be long-term, reflecting enduring changes in production processes. (Transient skill requirements are discussed more fully in a later section of the chapter.) In any event, these are jobs that are most likely to be filled through the transfer and retraining of existing personnel. The creation of new jobs is perhaps the hardest employment impact to forecast.

Clerical Workers

CURRENT EMPLOYMENT TRENDS

Clerical workers in manufacturing industries perform a variety of functions in both office and plant settings. Across manufacturing industries, 2,322,400 (11.5 percent) were employed in clerical positions in 1980; 2,215,334 (11.8 percent) were so employed in 1982, when economy-wide clerical employment was over 18.7 million (20 percent of total employment). Now, manufacturing technologies will affect both office and plant clerical workers, and the growing use of office automation will reinforce the displacing effects of PA in manufacturing. Table 31 shows the distribution of potentially vulnerable office and plant clerical occupations in selected metalworking industries.

Past growth in clerical employment in manufacturing, as in the rest of the economy, has reflected a substantial growth in company de-

[55]OTA case studies,

Table 31.—Clerical Employment, 980

	All industries		All manufacturing		Metalworking machinery and equipment		Office, computing, and accounting machines		Electrical industrial apparatus		Electronic components and accessories		Motor vehicles and equipment		Aircraft and parts	
Office machine operators	912,708	1.0%	147,499	0.7%	2,311	0.6%	6,762	1.6%	1,704	0.7%	3,302	0.6%	3,431	0.4%	6,424	1.0%
Computer operators	184,245	0.2	36,945	0.2	676	0.2	3,170	0.7	NA	NA	1,140	0.2	1,029	0.1	1,142	0.2
Order clerks	242,547	0.3	68,604	0.3	927	0.3	919	0.2	1,021	0.4	1,491	0.3	734	0.1	1,281	0.2
Payroll and timekeeping clerks	177,785	0.2	60,412	0.3	1,104	0.3	870	0.2	668	0.3	1,284	0.2	1,160	0.2	1,558	0.2
Personnel clerks	94,829	0.1	25,376	0.1	366	0.1	873	0.2	305	0.1	904	0.2	334	0.04	2,239	0.3
Procurement clerks	40,274	0.04	24,551	0.1	560	0.2	1,035	0.2	462	0.2	1,046	0.2	488	0.06	1,882	0.3
Production clerks	200,029	0.2	139,947	0.7	2,910	0.8	7,121	1.7	2,889	1.2	6,099	1.1	4,778	0.6	13,219	2.0
Shipping and receiving clerks	389,218	0.4	146,036	0.7	1,908	0.5	2,118	0.5	1,409	0.6	3,550	0.6	5,246	0.7	2,679	0.4
Stockroom and warehouse clerks	818,435	0.9	151,043	0.7	4,469	1.2	6,806	1.6	2,988	1.3	4,299	0.8	5,187	0.7	10,333	1.6
All clerical	18,521,980	0.0	2 297,379	11.3	40,429	10.9	69,320	16.1	28,213	11.9	57,235	10.3	47,973	6.2	90,760	13.9

NOTE: Percentages have been rounded

SOURCE: Bureau of abor Statistics. "Employment by Industry and Occupation, 980 and Projected 1990 Alternatives," unpublished data on wage and salary employment mand for information collection and processing, growth that has been facilitated by early uses of computers and office automation. Note that the continued presence of large numbers of keypunch operators attests to the slowness with which companies make major changes in data-handling and data-processing systems, especially those that represent major investments in hardware.

PROJECTED EMPLOYMENT IMPACTS

Programmable automation will affect clerical employment by computerizing the "paper trail" that follows materials and work-in-process through production. This is a direct outcome of the data-aggregating function of PA systems, which relate all types of tasks, from design through shipment, to a manufacturing database. Indeed, the Air Force ICAM program targets such functions as planning, scheduling, and other indirect or nonproduction functions, which underlie much production clerk employment, as principal candidates for automation. The development and storage of product plans through computer-aided design, the direct linkage of CAD to production equipment, and the computerization of planning, ordering, purchasing, billing, and inventory control will all act to reduce the demand for clerical services and personnel.

Clerical employment is most likely to change, at least in the near term, among larger firms because they are quicker to adopt computerized inventory and planning systems, and because they have greater information-flow needs and problems. For example, the Litton Office Product Center installed an automated system for order entry, inventory checking, receivable monitoring, and billing which cut time for these activities by 75 percent.[56] Larger firms are also more likely to adopt sophisticated automated materials handling systems and AS/RS, which is most economical in larger installations. Finally, reductions in company work forces as well as automated recordkeeping may affect personnel and payroll clerk employment. Of all occupational groups, production clerks, together with such other intermediaries as stockchasers and expediters, rank among the most likely to diminish in size with extensive automation and computer-integration.

Managers

Managers plan, organize, direct, and control various functions within firms. They may also do work similar to that of their subordinates.

CURRENT EMPLOYMENT TRENDS

In 1980, there were 1,328,160 managers and officers across the manufacturing sector, accounting for 6.58 percent of manufacturing employment. In 1982, there were 1,260,062 (6.7 percent). Nationally, employment of managerial personnel has been growing in all economic sectors, even during the recent recessions.* There were about 7.7 million managers, officials, and proprietors in 1982 nationwide. Lower level managers include "nonworking" or "blue collar" supervisors and clerical supervisors, who are counted with production and clerical workers, respectively. There were 705,307 (3.46 percent) blue collar supervisors and 66,841 (0.33 percent) clerical supervisors in manufacturing in 1980. Table 32 shows the distribution of managerial and supervisory personnel in the machinery and transportation equipment industries.

PROJECTED EMPLOYMENT IMPACTS

Programmable automation will alter the mix and number of managerial personnel. It will probably support growth in upper management ranks, for three reasons. First, the integration of databases and anticipated shifts in decisionmaking toward higher staff levels will increase the role of upper management in the production process. The push for so-called "top down control, " facilitated by computerization, inherently increases the role of upper

[56] Paul Gillin, "Last Piece of Automation Puzzle Fits for Firm, " *Computerworld*, Dec. 5, 1983.

*There were nearly 7 percent more managers and administrators in December 1982 than in January 1980, while overall employment fell 1 percent; however, unemployment for managers also grew in that period. See Karen W. Arenson, "Management's Ranks Grow, " *The New York Times*, Apr. 14, 1983.

Table 32.—Employment of Managerial and Supervisory Personnel, 1980

	Managers, officials, & proprietors		Nonworking blue-collar supervisors		Clerical supervisors	
	"Number	Percent	Number	Percent	Number	Percent
All industries	7,557,359	8.1	1,273,191	1.4	428,087	0.5
All manufacturing	1,195,743	5.9	705,307	3.5	66,841	0.3
Metalworking machinery and equipment .	28,190	7,6	10,119	2.7	862	0.2
Office, computing, and accounting machines	40,583	9.4	8,112	1.9	2,473	0.6
Electrical industrial apparatus	12,632	5.3	8,343	3.5	1,009	0.4
Electronic components and accessories . .	29,954	5.4	15,928	2.9	1,936	0.4
Motor vehicles and equipment	25,424	3.3	30,575	4.0	1,110	0.1
Aircraft and parts	48,746	7.4	24,391	3.7	1,914	0.3

NOTE Percentages have been rounded

SOURCE Bureau of Labor Statistics, Employment by Industry and Occupation, 1980 and Projected 1990 " unpublished data on wage and salary employment

management. Second, insofar as batch production, product variation, and competition grow, more managerial input will be required for product planning and market analysis. Growth in PA products and markets is itself a source of growth in managerial employment; many want-ads for managers refer to planned or existing new ventures, and they often refer to marketing responsibilities. Third, change in production technologies may create new operational units within firms, and associated needs for planning and management. Automation generally entails new work in database management, software quality assurance, and training-activities which may be undertaken by special staffs and managers.

Nevertheless, it is not clear how much new managerial employment the support needs of manufacturing automation will generate, especially where companies already have data-processing staffs. Also, more advanced systems that do not require mastery of special languages or formats, that include applications generators, or that entail distributed data processing lower the requirement for special, in-house personnel.

By contrast, the automation of data collection and transfer activities (e.g., through monitoring operation and performance characteristics of machines, and developing and transmitting machine operating instructions from CAD systems) is expected to lower the demand for lower and middle managers .57 Some observers predict that this will lead to an hourglass personnel structure among firms. In some cases, automation may bring about an upgrading of a management position. For example, added attention to materials requirements, production planning, and scheduling may make certain materials and inventory management activities into "white collar" functions. Where a few employees oversee a larger amount of equipment, fewer first-line supervisors may be needed. Indeed, with integrated systems, it is likely that a hybrid position containing attributes of formerly separate supervisory and subordinate operator jobs may emerge.

Other changes in the nature of managerial work are possible. A study evaluating prospects for computer operations managers generally suggested growing needs for capacity planning, performance monitoring, technical support, security management, and facilities management .[58] Also, a study of manufacturing firms concluded that:

> The new technology substantially changed the jobs of supervisors and middle-management, shifting the focus from watchdog and disciplinarian to planning, training, and communicating. [59]

Industry representatives frequently point to resistance among lower and middle manage-

[57] David Myers, "ACM Told OA May Squeeze Middle Managers Out of Jobs, " *Computerworld*, Oct. 31, 1983.

[58] " Higher Skills Needed: Study, " *Computerworld*, Apr. 18, 1983.

[59] Wickam Skinner, "Wanted: Managers for the Factory of the Future, " *The Annals of the American Academy of Political and Social Science, vol. 470,* November 1983.

ment as a principal obstacle to the spread of automation. Greater recognition of the potential of these technologies to displace such personnel may add to such problems.

Sales/Service

Sales and technical service personnel consult with potential and actual customers, conduct presentations and demonstrations, provide training, and install products. In 1980 there were 437,497 (z. 15 percent) sales workers employed in manufacturing. In 1982, there were 413,657 (2.2 percent). These included sales representatives or agents and sales clerks. Also in 1980, there were 5,165 (0.03 percent) adult education teachers employed in manufacturing industries. Finally, technical writers (in unknown number) comprise a related category.

Producers of PA, as well as independent consulting or service firms, are likely to demonstrate a growing need for technical sales and service or support personnel to serve their growing markets. On the other hand, automated management and office systems are likely to dampen demand for sales clerks.

Although industry representatives have complained of shortages of field-service personnel and trainers, it is difficult to judge the numbers of such people, because in many cases they wear several hats. Also, for products that are new and continually developing, it is to be expected that people with relevant expertise may be hard to find. For smaller, innovative firms, in particular, technology sales and support personnel tend to be engineers and other professionals. However, want-ads suggest that even large vendors of programmable automation use engineers-" applications engineers' –for marketing and pre- and post-sale support services. This situation reflects not only the technology-intensive nature of PA products but also the fact that experienced engineers commonly move into sales, management, and other nonproduction positions. Such individuals are likely to be counted as engineers in occupational statistics.

Want-ads suggest that PA vendors, like other manufacturers of technical products, prefer sales representatives with technical college degrees, but will consider others with relevant experience. Similar preferences may exist for trainers. Predictably, selection criteria for sales managers also emphasize relevant experience. Relevant experience may include a background in sales or use of computer and business systems, or in manufacturing or PA sales.

Shift in Skills and Occupational Mix

As revealed by the preceding discussion of skill requirements and occupational trends, the proportions of skills and occupations found in manufacturing will shift substantially because of programmable automation. In fact, to date, this impact has been more striking than any change in the level of employment. While it is too soon to forecast precise numerical changes, the directions of change are clear. In some cases, the effect will be to reinforce the long-term shift toward white-collar employment; in other cases—notably, the negative effect on clerical opportunities-the long-term effect will differ from past shifts. This section describes the overall pattern of change in occupational mix and discusses the income implications of such change.

Shift Toward White Collar/ Salaried Employment

The broad—and long-term—tendencies are for employment opportunities of:

- engineers and computer scientists; technicians; and mechanics, repairers, and installers, on the whole, to rise-although specific occupations (e.g., drafters) will face diminishing opportunities;

- craftworkers (excluding mechanics), operatives, and laborers—especially the least skilled doing the most routine work—to fall;
- plant and perhaps other clerical personnel to fall; and
- managers and technical sales and service personnel to rise, although lower and middle management opportunities among users may fall.

Thus, a shift toward nonproduction or "white-collar" employment appears evident. Table 33 lists key occupations, 1980 employment levels, and the directions of potential change. *

'* However, changes in the mix of occupations do not guarantee a rise in white-collar employment in all cases.

Demonstrated Impact of Individual Technologies

Studies of the impacts of single automation technologies provide detailed evidence in support of a relative shift toward white-collar employment. For example, the Upjohn Institute forecast displacement, by 1990, of 100,000 to 200,000 production worker jobs due to robots alone, compared with creation of 10,000 to 20,000 jobs for maintaining robots and under 11,000 for robot applications engineering. Ayres and Miller of Carnegie-Mellon University forecast the potential displacement of 1 million to 4 million production worker jobs by robots, over a period of at least 20 years'"

*"Hunt and Hunt, op. cit.; and Robert U. Ayres and Steven M. Miller, "Robotics and Conservation of Human Resources, " *Technology in Society, vol. 9, 1982.*

Table 33.— 1980 Employment for All Manufacturing Industries, Selected PA-Sensitive Occupations

	Number	Percent	Long-term direct ion-- of change
Engineers	579,677	2.85	+
Electrical	173,647	0.85	+
Industrial	71,442	0.35	+
Mechanical	122,328	0.60	+
Engineering and science technicians	439,852	2.16	+
Drafters	116,423	0.57	
NC tool programmers,	9,371	0.05	–
Computer programmers	58,622	0.29	–
Computer systems analysts	42,404	0.21	+
Adult education teachers	5,165	0.03	+
Managers, officials, and proprietors.	1,195,743	5.87	?
Clerical workers	2,297,379	11.28	
Production clerks	139,947	0.69	
Craft and related workers.	3,768,395	18.51	–
Electricians	126,001	0.62	+
Maintenance mechanics and repairers	391,524	1,92	+
Machinists, tool and die makers	356,435	1.75	
Inspectors and testers	538,275	2.64	–
Operatives.	8,845,318	43.44	–
Assemblers	1,661,150	8.16	
Metalworking operatives	1,470,169	7.22	
Welders and flamecutters	400,629	1.97	
Production painters	106,178	0.52	–
Industrial truck operators	269,105	1.32	–
Nonfarm laborers.	1,576,576	7.74	
Helpers, trades.	100,752	0.49	
Stockhandlers, order fillers	104,208	0.51	
Work distributors	16,895	0.08	
Conveyor operators	31,469	0.15	

Note Data refer only to wage and salary workers

SOURCE Bureau of Labor Statistics, "Employment by Industry and Occupation, 1960 and Projected 1990 Alternatives. " un published data (see table 34). And a German study found that when NC machine tools were introduced, the least skilled personnel (machine operators) were most likely to be laid off, while higher skilled programmers, toolsetters, and mechanics were likely to be retained, and even more brought into the firm.[61]

A study of the effects of advanced telephone switching technologies showed that at Bell Canada, despite growth in output, technology limited growth in total man-hours of labor per year between 1952 and 1972 while producing large shifts in the occupational mix. The person-hour share of the least skilled category, operators, fell by over 20 percent while the shares of plant craftsmen and clerical personnel each rose by around 5 percent, and the "whitecollar worker" share, least affected by technology change, rose by over 9 percent. The authors of that study concluded that new telecommunications technology outweighed change in labor costs as the cause of employment shifts, having the greatest effect on employment of the least skilled (and least expensive) workers.[62] The pattern of large decline for the least skilled "production" workers and small increases among other categories is likely to occur with the introduction of programmable automation in manufacturing.

Finally, similar trends emerge from a survey of workers in the Japanese electrical machine industry. It was reported that, when microelectronics was introduced into products or production processes, employment of "permanent workers" in machining, assembly, inspection, and quality control was likely to fall, while employment of production engineers was likely to rise or remain constant.[63]

Overall Effects

Occupational demand shifts stimulated by PA reinforce a long-term growth in the proportion of nonproduction workers employed in manufacturing industries. For example, between 1945 and 1979, the nonproduction worker proportion in the nonelectrical machinery industry rose from 24.2 to 34.4 percent. By comparison, the proportion for the highly automated chemicals and allied products industry rose from 22.5 to 42.8 percent in the same period. The trends within manufacturing are paralleled by trends within the economy as a whole; employment in craft, operative, and laborer positions overall is now about one-third of total employ ment.[64] The broad occupational shift reflects both technology change and the growth in nonmanufacturing employment: In 1940, there were 300 manufacturing jobs per 100 service industry jobs; in 1980 there were 113.[65]

Studies of the effects of microelectronics (and telecommunications) technologies on other economies show similar tendencies. For example, an OECD study drawing on research in several countries identified the following broad trends:

- within manufacturing industries, a decline in the proportion of production workers engaged in low-skill, rote activities such as assembly;
- within services, a decline in the proportion of more routine information-handling occupations (e.g., low-skilled clerical);
- within all sectors, a decline in the proportion of lower managerial and supervisory occupations, with remaining personnel

[61]Werner Dostal and Klaus Kostner, "Changes in Employment With the Use of Numerically Controlled Machine Tools' (Mitteilungen aus der Arbeitsmarkt- und Berufsforschung), 1982.

[62]See Michael Denny and Melvyn Fuss, "The Effects of Factor Prices and Technological Changes on the Occupational Demand for Labor: Evidence From Canadian Telecommunications, " *The Journal of Human Resources, vol.* 17, No. *2, 1983.* The authors note that, "The force of automation can be seen from the fact that had technical change not occurred, the demand for operators would have increased over the 1952-72 period by 4 percent per annum rather than declining by 3 percent per annum. Similarly, zero output growth would have meant that the decline in operator demand would have increased to *7* percent per annum" (p.175).

[63]Denki Roren, "Surveys on the Impacts of Micro-Electronics and Our Policies Towards Technological Innovation, ' paper presented at the 4th IMF World Conference for the Electrical and Electronics Industries, Oct. 3-5, 1983.

[64]U.S. Department of Labor, Bureau of Labor Statistics, *Employment and Earnings,* May 1983, p. 179.

[65]"Jobs in Nation's Service Industries Continue Rise in Recession: Set New Record, Top Manufacturing Total for First Time, " *News,* U.S. Department of Labor, Bureau of Labor Statistics—Middle Atlantic Region, Dec. 8, 1982.

Table 34.—Carnegie-Mellon University Study Estimates

	Potential for robotization[a]									
	Level I robot		Level II		Operatives[b]		Potential displacement			
							Sector 34-37		Sector 33-38	
	Range percent	Average percent	Range percent	Average percent	Sector 34-37	Sector 33-38	I	II	I	II
Drill press/boring machine	25-50	30	60-75	65	104,050	113,210	31,215	68,933	33.963	73,587
Filer, grinder, buffer	5-35	20	5-75	35	77,360	103,430	15,472	27,076	2,086	36,201
Gearcutting, grinding, shaping.		10		50	11,070	11,670	1,107	5,535	1,167	5,835
Grinding/abrading machine operator	10-20	18	20-100	50	97,090	109,680	17,476	48,545	19,742	54,840
Lathe/turning machine operator	10-20	18	40-60	50	130,260	141,560	23,447	65,130	25,481	70,780
Machine tool operator, combination	10-30	15	5-60	30	142,750	154,220	21,413	42,825	23,133	46,266
Machine tool operator, NC	10-90	20	30-90	49	41,900	45,020	8,380	20,531	9,004	22,060
Machine tool operator, toolroom	1-5	3	4-60	50	33,410	36,160	1,002	16,705	1,085	18,080
Machine tool operator, setter		*10*		50	47,260	51,490	4,726	23,630	5,149	25,745
Milling/planing machine operator	10-20	18	40-60	50	58,900	63,230	10,602	29,450	11,381	31,615
Sawyer, metal		20		50	10,660	15,180	2,132	5,330	3,036	7,590
Subtotal, metalcutting machines					754,710	844,850	136,972	353,690	135,227	392,599
Coil winding	1540	24	15-50	40	26,570	33,550	6,377	10,628	8,052	13,420
Drop hammer operator		15		70	2,990	2,950	449	2,093	449	2,093
Forging press operator		15		70	6,500	7,190	975	4,550	1,079	5,033
Forging/straightening roll operator		15		70	1,000	2.840	150	700	426	1,988
Header operator		20		70	5,080	5,080	1,016	3,556	1,016	3,556
Power brake/bending machine		20		70	33,240	35,240	6,648	23,268	7,004	24,514
Press operator/plate print		20		70	4,230	4,230	846	*2,961*	846	2,961
Punch press operator	10-100	15	60-80	70	159,890	171,710	23,984	*111,923*	25,757	120,197
Punch press setter		15		70	16,080	16,840	2,412	11,256	2,526	*11,788*
Riveter (light)	5-100	15	10-100	30	9,090	9,090	1,364	2,727	1,364	2.727
Roll forming machine		20		70	4,320	11,030	864	3,024	2,206	7,721
Shearer/slitter operator		20		70	22,450	28,660	4,490	15,715	5,732	20,062
Subtotal, metalforming machines					291,440	344,310	49,575	192,401	56,467	216,060
Conveyor operator/tender		10		30	18.070	20,240	'1,807	5,421	2,024	6,072
Die casting machine operator	5-15	5	10-20	10	6,530	14,670	327	653	734	1,467
Dip plater	20-100	40	50-100	77	7,780	9,500	3,112	5,991	3,800	7,315
Electroplate	5-40	20	5-60	55	27,350	29,770	5,470	15,043	7,954	16,374
Plater helper		30		100	26,100	26,560	7,830	26,100	7,968	26,560
Fabricator, metal		*10*		30	5,910	5,910	591	1,773	591	1,773
Fabricator, plastic		*10*		30	1,970	1,970	197	591	197	591
Furnace operator/cuppola tender		20		50	4,420	14,490	884	2,210	2,898	7,245
Heater, metal		20		*100*	2,070	5,010	414	2,070	1,002	5,010
Heat treater, annealer	5-50	10	5-90	46	14,770	23,440	1,477	6,794	2,344	10,782
Injection/compression mold operator (plastic)		20		50	24,910	29,830	4,982	12,455	5,966	14,915
Inspector	5-25	13	5-60	35	228,530	269,650	29,709	79$986	35,055	94,378
Laminator, preforms		20		50	10,160	10,160	2,032	5,080	2,032	5,080
Machine operator, n.e.c.[c]	10-50	16	20-65	25	13,020	38,590	2,083	3,255	6,174	9,648
Molder, machine		20		50	5,650	18,540	*1,130*	2,825	3,708	9,270
Packager, production	1-40	16	2-70	41	55,480	75,640	8,877	22,747	12,102	30,939
Painter, production	30-100	44	50-100	66	74,380	78,540	32,727	49,091	34,558	51,836
Pourer metal	5-20	10	10-30	24	1,280	13,280	128	307	1,328	3,187
Sandblaster, shot blaster	10-100	35	10-100	35	6,290	10,030	2,202	2,202	3,511	3,511
Screwdriver operator (power)		*10*		50	3,420	3,420	342	1,710	342	1,710
Tester	1-10	8	5-30	12	51,470	62,890	4,118	6,176	5,031	7,558
Wirer, electric	0-10	9	10-50	28	22,940	26,520	2,065	6,423	2,387	7,426
Subtotal, miscellaneous machines					612,500	788,650	112,504	258,903	141,700	322,647
Joining (welding)	10-60	27	10-90	49	319,040	344,280	86,141	156,330	92,956	168,697
Assembly	3-20	10	20-50	30	1,182,650	1,318,750	118,265	354,795	131,875	395,625
Total of subtotals + joining + assembly					3,160,340	3,640,840	503,457	1,316,119	558,220	1,495,628

[a] Time frame is uncertain authors refer to "eventual" displacement potential
[b] Employment figures are from Bureau of Labor Statistics, *Occupational Employment in Manufacturing Industries* (Washington, D C U S Government Printing Office, 1977)
[c] n e c . Not elsewhere classified

NOTE The italicized numbers are estimates by Robert U Ayers, based on similarity

SOURCE *The Impacts of Robotics on the Workforce and Workplace,* Carnegie-Mellon University, June 1981

more restricted to preparing and transmitting information to upper management;
- growth in the proportion of occupations installing, operating, and repairing new equipment and providing related support; and
- some deskilling of tasks in some craft occupations due to transfer of prior operator functions to machines.[66]

However, it is imprudent to simply take past trends as accurate forecasts of the future. For example, there are indications that the occupational shift is not inexorable, at least in the short term. Researchers at New York University, in the study cited at the beginning of this chapter, forecast the effects on labor demand in 1990 and 2000 of a growing use of computer technology in manufacturing, office, health-service, and education settings. They concluded that the overall trend toward white collar employment would continue, but that the shift would be greater for the slower of two alternative trends for the diffusion of computer technologies.

Their analysis suggests that the large size of the investment in capital goods required for the diffusion of computer-based technologies could buoy manufacturing industry and production occupation employment throughout this century. While computerization reduces demand for labor overall, because of anticipated slow growth in labor supply it can serve to avert potential shortages of certain types of personnel rather than create unemployment. Although, like any other modeling exercise, that analysis is shaped by its underlying assumptions, it shows how output levels can determine employment mix as well as level. Thus, output levels, economic performance and growth can be seen to be vital to employment.

PA Producer Employment Mix

The emerging occupational mix found in automation producers may indicate future trends for the metalworking industries generally-and perhaps for the rest of the manufacturing sector as well. The Upjohn Institute, for example, suggested that two-thirds of the jobs among robot producers would be white-collar, including professionals, technicians, administrators, sales, and clerical workers. * Researchers at New York University, drawing on discussions with the leading robot producer (Animation), also estimated that about two-thirds of employment in the robot industry would be white-collar, although it had different detailed estimates (see table 35). Finally, a similar appraisal was provided in recent congressional testimony by Walt Weisel, chief executive of a robot manufacturer (Prab Robots) and president of the Robotic Industries Association (formerly the Robot Institute of America). Weisel forecast new jobs in sales, applications engineering, research and development, and field service among producers, as well as new maintenance and manufacturing process jobs among users.** These examples reflect the fact that production work is relatively limited among producers of programmable automation (see ch. 7}; its role is also declining among other manufacturers.***

The implications of the employment mix found among producers of automated equipment can be seen by contrasting the staffing profiles of the electronic and computing machinery and engineering and architectural services

[66] OECD, *Information Activities, Electronics and Telecommunications Technologies*, Paris, 1981. An econometric study of the Canadian economy described in that OECD volume suggested that, as capital intensity grows, complexity of operations also grows, making planning and coordination—and associated personnel—more necessary. It also found that as the cost of capital or equipment falls relative to other costs, demand for "information labor" rises, while demand for "noninformation labor" falls.

*That study estimated that employment by domestic robot manufacturers was approximately 2,000 persons in 1982 and would grow to between 9,000 and 17,000 by 1990. Hunt and Hunt, op. cit.

**Testimony during hearings before the House Committee on Small Business, Subcommittee on General Oversight and the Economy, May 17, 1983.

***The Upjohn Institute also estimated that there would be about 8,000 to 16,000 jobs associated with supplying hardware components to robot producers by 1990. This latter estimate assumes domestic sourcing of hardware; it will overstate actual supplier employment potential if companies continue to expand their imports of robotic hardware.

Table 35.—Estimates of Robot Manufacturer Staffing Profiles, 1982

Occupation	Robot manufacturing (%)
New York University[a]	
Electrical engineers	12.1%
Industrial engineers	2.2
Mechanical engineers	4.4
Other engineers	8.3
Computer programmers	2.1
Computer systems analysts	0.9
Other computer specialists	0,3
Personnel and labor relations workers	0.3
Other professional, technical	8.2
Managers, officials, proprietors	9,0
Sales workers	4.0
Stenographers, typists, secretaries	5,6
Office machine operators	0,9
Other clerical	9.2
Electricians	0.9
Foreman, n.e.c	0.8
Machinists	2.3
Other metalworking craftworkers	1.5
Mechanics, repairers	0,8
Assemblers	14,7
Checkers, examiners, Inspectors	2,8
Packers and wrappers	0,4
Painters	0.7
Welders, flame cutters	0.9
Other operatives	5,6
Janitors and sextons	0,4
Laborers	0.7
Total	100.0

Occupation	Robot manufacturing (%)
Upjohn Institute[b]	
Engineers	23.7%
Engineering technicians	15.7
All other professional and technical workers	4,2
Managers, officials, proprietors	6.8
Sales workers	3.4
Clerical workers	13.9
Skilled craft and related workers	8.4
Semiskilled metalworking operatives	4,2
Assemblers and all other operatives	19,0
Service workers	—
Laborers	0.7
Farmers and farmworkers	—
Total	100,0

Columns may not add to total due to rounding
nec = not elsewhere classified

SOURCES: [a]Wassily Leontief and Faye Duchin, *The Impacts of Automation on Employment, 1963-2000*, final report, New York University Institute for Economic Analysis, April 1984. Data based on staffing of Unimation, Inc (now part of Westinghouse).
[b]H. Allan Hunt and Timothy L. Hunt, *Human Resource Implications of Robotics*, The W. E. Upjohn Institute for Employment Research, 1983

industries with those of the motor vehicles and parts, metalworking machinery, and primary metals industries (see table 36). The electronic and computing machinery industries have primarily employed professional and technical workers (39 percent) and other white-collar personnel, as has the engineering and architectural services industry (69 percent professional and technical). By contrast, employment in the other industries has a more even distribution over a larger range of occupations, with many more opportunities in production jobs. For example, craft and kindred workers and operatives each comprise about a third of the employment in metalworking machinery; they have comprised 20 percent and over 50 percent, respectively of motor vehicle employment.

The staffing contrast is instructive, because employment opportunities for producing PA will be more like those in the computer industry than in conventional metalworking manufacturing. As noted by the Upjohn Institute:

> The most remarkable thing about the job displacement and job creation impacts of industrial robots is not that more jobs are eliminated than created; this follows from the fact that robots are labor-saving technology designed to raise productivity and lower costs of production. Rather, it is the skill-twist that emerges so clearly when the jobs eliminated are compared to the jobs created . . . We submit that this is the true meaning of the so-called robotics revolution.[67]

[67]Hunt and Hunt, op. cit., p. 172.

Table 36.—Industry Staffing Pa'tern Contrasts

	Metalworking machinery and equipment		Motor vehicles and parts		Office, computing, and accounting machinery		Computer and data-processing services		Engineering and architectural services	
Professional, technical, and related workers	32,617	8.8%	45,417	5.9%	139,922	32.5%	86,351	29.5%	349,063	62.7%
Managers, officials, and proprietors	28,190	7.6	25,424	3.3	40,583	9.4	37,244	12.7	58,947	10.6
Sales workers . .	7,207	1.9	3,837	0.5	4,107	1	9,965	3.4	2,345	0.4
Clerical workers	40,429	10.9	47,973	6.2	69,320	16.1	147,665	50.4	85,066	15.3
Craft and related workers	99,306	26.7	161,297	20.8	52,055	12.1	3,982	1.4	12,591	2.3
Operatives	146,706	39.5	520,413	54.3	112,377	26.1	5,242	1.8	41,557	7.5
Service workers . .	7,496	2	22.003	2.8	4,771	1.1	1,681	0.6	4,786	0.9
Nonfarm laborers	9,544	2.6	47,433	6.1	7,677	1.8	672	0.2	2.346	0.4

NOTE: Percentages have been rounded.

SOURCE: Bureau of Labor Statistics, "Employment by Industry and Occupation, 1980 and Projected 1990 Alternatives," unpublished data on wage and salary employment.

The contrast in staffing patterns implies that there will be relatively few opportunities for people to move easily from other metalworking manufacturing jobs into automation-producer jobs. It also implies that there may be fewer opportunities for promotion from production to nonproduction work.

Intercompany Patterns

Where automation is part of broader process changes that also include changes in business relations between manufacturers and their suppliers or distributors, occupational shifts within companies may mask offsetting or amplifying trends in related firms (upstream or downstream). Computer links between facilities, in particular, may affect facility staffing. Eaton, for example, is implementing a computer-aided design and manufacturing system that will share information about product design, process planning, materials requirements, and costs among computers at 200 Eaton manufacturing facilities (and many subcontractors). Such a network will reduce engineering and other personnel requirements per facility."

As was discussed earlier, the spread of CAD and its integration with CAM may alter companies' decisions on whether to contract out for drafting and other design services. In addition, the growth of automation service and consulting firms will affect producer and user hiring of applications engineering staffs. While manufacturers have increasingly contracted out for "producer services" such as accounting, food services, and security, programmable automation may reinforce or counter this trend for individual services, thereby influencing staffing patterns among both manufacturing and service firms.

Transient Skill Requirements

One factor that cushions employment adjustment in the short term but presents challenges for long-term planning and adjustment is the tendency of early or simpler types of programmable automation (and other computer applications) to require work that is found to be no longer needed with more advanced technology. A classic example, in the case of computers, is keypunching. Keypunchers are still in demand in the United States (over 57,000 were employed in 1980) because many computer users cannot afford to jettison outmoded data-entry systems when improved technologies come along. The availability of new technology thus does not guarantee an immediate demand for new skills and staffing. However, keypunching was the only computer field to experience declining employment in the 1970's.

The most obvious areas in which skill requirements associated with PA maybe short-lived, at least in some firms, are data entry, data transfer, and programing. One major aerospace user of PA, for example, anticipates a major reduction in its use of engineering and computer support personnel with the integration of various computer-based systems.[69] As early as 1977, NC users responding to a survey conducted by MIT researchers "reported a desire to reduce both programing and maintenance costs by increasing their dependence on computer sophistication and reducing the need for highly skilled technicians. "7°

At present, different automation equipment and systems have different programing and data-processing needs. Integration of those systems where applicable, development of a standard language, and/or other developments (see ch. 3) may bring about a sharp reduction in the amount of programing that is necessary. CAD, CAE, and computer-based management systems typically use commercial software packages and involve little programing by users. Although data entry is necessary to establish databases, after the initial input

[68] *American Metal Market/Metalworking News*, May 16,1983.

[69] OTA case study.

[70] Robert T. Lund and Christopher J. Barnett, "Numerically Controlled Machine Tools and Group Technology: A Study of U.S. Experience, " MIT Center for Policy Alternatives, Jan. 13, 1978.

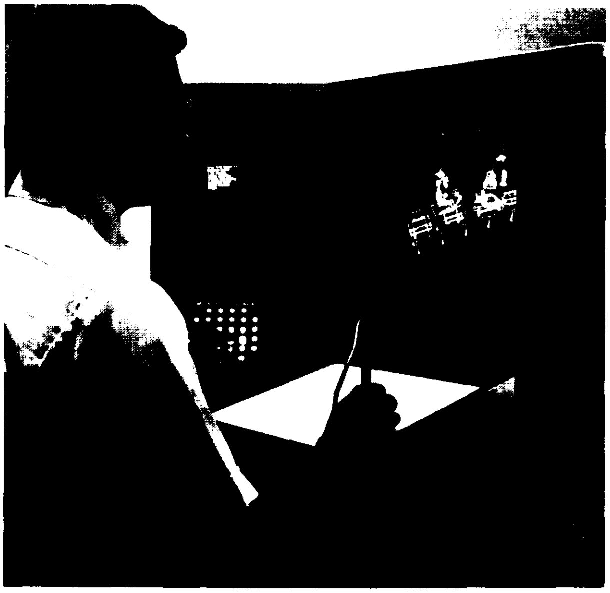


Photo credit McDonnell Doug/as Automat/on Co

Graphics-based offline robot programing using a CAD system

stage updating may be handled by professionals using distributed, interactive systems.*

Robots are usually programed with easy-to-use software that generally does not require programing skills, and they have tended to be reprogramed infrequently. Moreover, direct links between robots and CAD or CAE systems will further reduce robot programing. Similarly, NC programing is becoming simpler, and direct links to CAD or CAE systems will reduce programing requirements. While users may develop greater needs for persons capable of adapting programs, they will have less need for program creators, although such persons may remain important to suppliers of PA equipment systems.

Transient jobs tend to persist among small firms longer than among larger ones, inasmuch as small firms are less able to adopt newer technology. However, the development of cheaper, smaller, easier-to-use PA systems —such as those currently fueling market growth for CAD and CNC, in particular-will hasten their adoption by smaller firms during this decade and the next (see ch. 7).*

Qualification Trends

Evidence from the United States and other countries suggests that, though automation is simplifying production tasks, employers are hiring better qualified, more skilled personnel. Insofar as this occurs, simple contrasts in occupational employment levels will not be accurate indicators of changes in skill requirements.

Research from Japan and West Germany brings out the contrast between employee qualifications and skill requirements:

- A Japanese survey reported that the spread of microelectronics was associated on the one hand with substantial growth in employment of high school and college graduates with science and engineering majors and on the other hand with growth in the number of machine operators doing simple or unskilled tasks.[71]
- A Japanese case study of automation in software development found that companies hired better educated staff over time but adopted automated techniques aimed

*Computer-industry representatives see improved software and easier-to-use systems as a response to a perceived shortage of programmers and other data-processing personnel. At an April 1983 conference, one software company spokesman contended, "What we need is to make microcomputers easy enough to use so that end users can control their destiny. " See Robert Batt, "Micros Seen Holding Key to DPer Lack, " *Computerworld*, Apr. 25, 1983.

*To put the timing issue into perspective, note that most job openings represent the replacement of personnel, rather than employment growth. Replacement hiring occurs not only because of deaths, retirements, and resignations, but also because people move between occupations as well as jobs. Replacement needs are one reason why BLS and others forecast that most 1980's job openings will occur in existing occupations, and that PA will have a negligible effect on many of the occupations expected to grow the most. Indeed, although 5 computer-related occupations experienced dramatic employment growth (ranging from 28 percent for data-entry personnel to 477 percent for other computer specialists) between 1972 and 1982, as a group they accounted for slightly more than 5 percent of overall job growth in that period. See Ronald E. Kutscher, testimony before the House Committee on Small Business, Subcommittee on Oversight and the Economy, hearings on "The Impact of Robots and Computers on the Workforce of the 1980' s," May 18, 1983.

[71]"Ministry of Labor Report on Microelectronics and Its Impact on Labor, " cable from American Embassy (Tokyo) to U.S. Secretary of State, August 1983.

at simplifying work, allowing employees to "supervise' automated processes. Work tasks were changed in response to shortages of experienced personnel.[72]

- A Japanese survey of electrical machinery industry workers reported that operators of microelectronics-equipped machines in machine shops (and to a lesser extent in assembly shops) perceived a need to understand computers, progr aming, electricity, and electronics, while machine "supervision' and monotonous routine work increased.[73]
- A West German study of the employment effects of NC machine tools reported that workers increasingly perceived a need for "professional training, " while their responsibilities shifted from machine operation to machine "supervision."[74]

The preference of employers to hire (or retain) well-educated personnel, both in the United States and abroad, suggests that higher education or skill may be regarded as an indicator of other attributes such as responsibility (desired because of growing investments in equipment) or an ability to solve problems and troubleshoot (desired because of growing dependence on equipment and the costs of a breakdown). Thus, the Japanese survey of electrical machinery workers noted a need for "attitudes such as meticulousness and accuracy, the readiness to learn new things, and so forth" that allow prompt decisionmaking and quick responses.

In the short term, employers may continue to employ personnel who are on average more or less skilled than necessary. This is because most companies are inexperienced with programmable automation, especially the production technologies, and are not yet familiar with their exact skill requirements and capabilities. In the long term, as experience is gained, companies may employ more lower skilled people plus a few highly skilled people working at higher levels. This may come about because PA can lower skill requirements as well as job numbers at low and middle levels of organizations, and because companies generally try to reduce the amount of skill they have to pay for. On the other hand, companies try to avoid wholesale replacement of skilled categories, since skilled workers are generally more productive than others. The transition in skill mix is likely to be gradual, and it will vary among firms and industries.

Compensation Patterns

Occupational shifts affect wage levels and in turn influence the income distribution and the buying power of consumers. The shifts discussed in this chapter will alter wage patterns both within the manufacturing sector and between it and other sectors. While short-term trends can be identified, long-term implications are less clear; they depend on many factors besides technology change.

A major implication of the shift to "white-collar" or salaried jobs, given contemporary wage patterns, is a reduction in access to well-paying jobs for individuals with a high school education or less, individuals who have traditionally found ready employment in the manufacturing sector (and in production jobs in particular). In many cases, manufacturing personnel earn higher pay than their skill levels or educational attainment would suggest, in part because of collective bargaining. By contrast, many low-skill service jobs pay less and offer less job security, in part because of the absence of collective bargaining. Lack of proper education and training or employer prejudices, as well as a reduction in available job opportunities, may restrict the movement of such individuals into higher skilled jobs in the manufacturing sector, while technology change

[72] Japan Labor Association, "A Special Study Concerning Technological Innovation and Labor-Management Relations, " interim report, June 1983. Also, note that this experience is similar to conditions observed following the introduction of NC machine tools.

[73] Denki Roren, "Surveys on the Impacts of Micro-Electronics and Our Policies Toward Technological Innovation, " paper presented at the 4th IMF World Conference for the Electrical and Electronics Industries, October 1983.

[74] Werner Dostal and Klaus Kostner, "Changes in Employment With the Use of Numerically Controlled Machine Tools, " (Mitteilungen aus der Arbeitsmarkt- und Berufsforschung), 1982.

and import competition may reduce the total number of manufacturing jobs. *

Figure 16 contrasts the earnings distribution for agriculture and industry and for services in 1971 and 1981. Lower levels of compensation for the service sector as a whole reflect the relative lack of unionization, the prevalence of small firms, the greater role of part-time work, and the predominance of women.** Table 37 shows the distribution of average earnings by industry; table 38 shows that average earnings in metalworking industries are higher than those in durable manufacturing overall; and table 39 shows earnings levels by occupation in machine-tool industries.

As the above contrasts suggest, employees displaced from manufacturing employment may suffer reductions in earnings, income, and job security if they move into new jobs in service industries or into other jobs in manufacturing that are not subject to collective bargaining. The losses are especially likely for older workers, whose wages would have grown with seniority.

Changes in job mix may affect the distribution of income more than the level of income overall. In very general terms, PA and other factors will contribute to long-term growth in output and, therefore, aggregate income. While shifts in job mix may depress wage growth, returns on invested capital may grow, shifting spending power from workers to investors (many of whom are workers themselves). This shift may be compounded inasmuch as wage earners are more likely than investors to spend on relatively labor-intensive goods and services, as some evidence suggests. *

Past trends suggest that technological change and the declining share of manufacturing jobs in the economy have eroded midlevel job and income opportunities, polarizing the work force and income distribution (see table 40). Noyelle, for example, argues from an analysis of private sector earnings distributions that:

> Medium jobs are shrinking in importance across the economy, in good part because employers are increasingly emphasizing the concentration of skills in a relatively narrow stratum of upper level jobs, while dealing with the rest of their work force as a buffer that can be adjusted over the course of the economic cycle.[75]

However, it is not clear that this pattern will continue in the long run. While long-term changes in wage patterns and income distribution are beyond the scope of this report, several observations can be made here.

Stanback and Noyelle attribute the loss of midlevel jobs in manufacturing to "increased separation between production and administrative functions . . . and the increased division of the work process within both production and corporate administration."[76] Programmable automation should counteract these trends, because it aims to integrate production and administration. Also, PA may help to reduce employment fluctuations among firms in the future because it simultaneously lowers labor requirements and encourages broader job descriptions, which may make workers less "dispensable." Moreover, as suggested by the discussion of occupational trends above, PA may so blur occupational

'*A survey performed by Westat for OTA in August 1982 showed a propensity of firms—especially those that are relatively large or relatively heavy users of automation-to train professionals and high-skilled production workers to work with automated equipment.

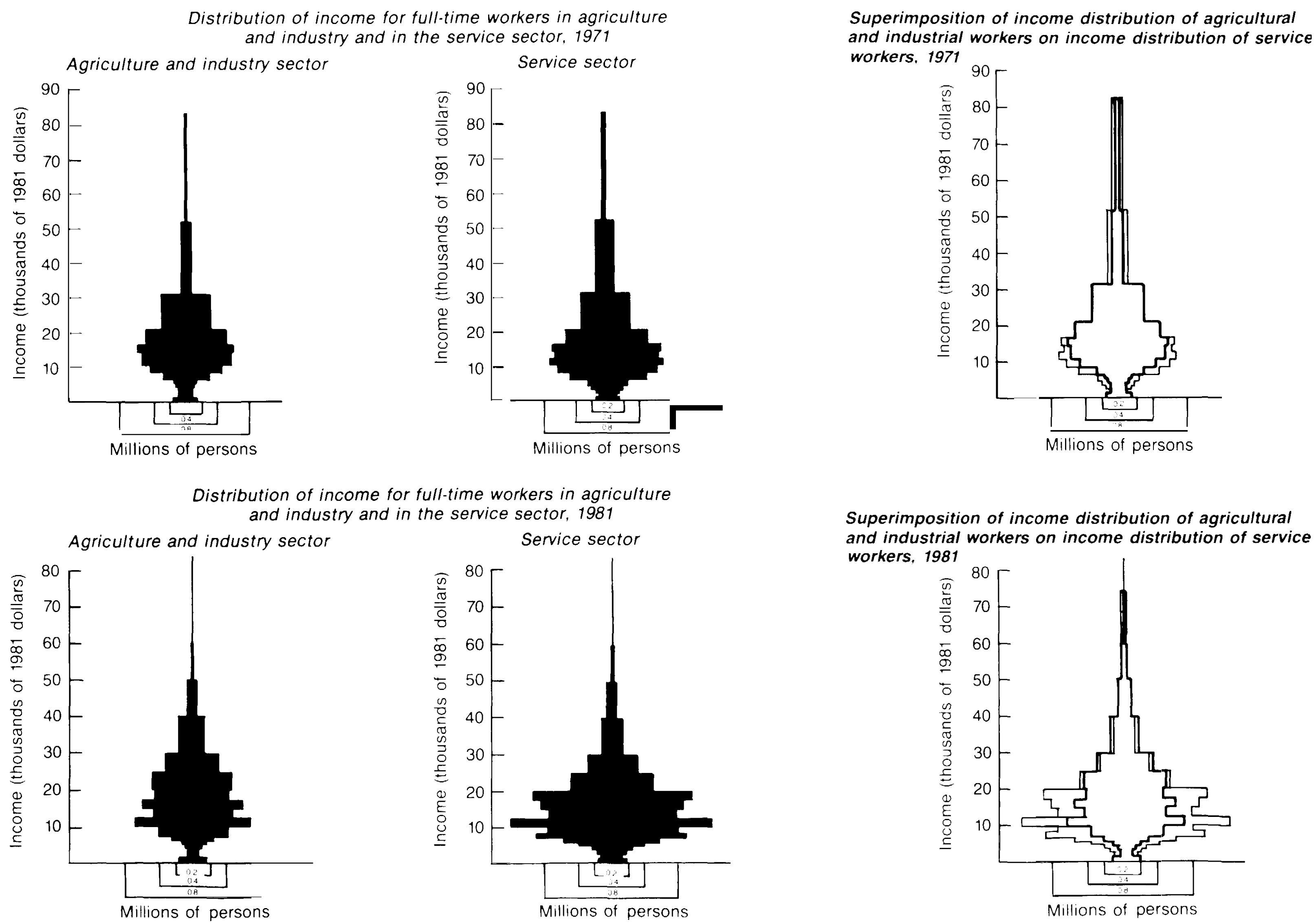
**"A large share of the rapidly increasing service sector employment has involved work traditionally done by women at low pay, and throughout the period (1950-81) there has been a marked tendency for much of the new white-collar work to be defined as women's work, paid for at relatively low rates and performed by women and until recently by young workers from the baby-boom generation. " Thomas M. Stanback, Jr., "Work Force Trends, " *The Long-Term Impact of Technology on Employment and Unemployment* (Washington, D. C.: National Academy Press, 1983).

*Note that between 1968 and 1982, personal consumption expenditures consistently grew faster than GNP; consumer spending is the largest component of GNP. See Arthur J. Andreassen, "Economic Outlook for the 1990's: Three Scenarios for Economic Growth, " *Monthly Labor Review*, November 1983.

[75]Thierry J. Noyelle, "People, Cities, and Services, " *The Entrepreneurial Economy*, June 1983.

[76]Thomas N. Stanback, Jr., and Thierry J. Noyelle, *Cities in Transition* (Totowa, N. J.: Allanheld, Osmun & Co., 1982).

Figure 16.—Sectoral Earnings Patterns



SOURCE: John S. Reed, "Employment and Unemployment in the Service Sector," *The Long-Term Impact of Technology on Employment and Unemployment* (Washington, D.C.: National Academy Press, 1983).

Table 37.—Earnings by Industry (gross hours and earnings of production or nonsupervisory workers[a] on private nonagricultural payrolls by industry division and major manufacturing group)

Industry	Average weekly hours				Average hourly earnings				Average weekly earnings			
	1979	1980	1981	1982	1979	1980	1981	1982	1979	1980	1981	1982
Total private	35.7	35.3	35.2	34.8	$6.16	$6.66	$ 7.25	$ 7.67	$219.91	$235.10	$255.20	$266.92
Mining	43.0	43.3	43.7	42.6	8.49	9.17	10.04	0.83	365.07	397.06	438.75	459.23
Construction	37.0	37.0	36.9	36.7	9.27	9.94	10.82	1.55	342.99	367.78	399.26	426.45
Manufacturing	40.2	39.7	39.8	38.9	6.70	7.27	7.99	8.50	269.34	288.62	318.00	330.65
Overtime hours	3.3	2.8	2.8	2.3	—	—	—	—	—	—	—	—
Durable goods	40.8	40.1	40.2	39.3	7.13	7.75	8.54	9.05	290.90	310.78	343.31	355.06
Overtime hours	3.5	2.8	2.8	2.2	—	—	—	—	—	—	—	—
Lumber and wood products	39.4	38.5	38.7	38.0	6.07	6.55	6.99	7.50	239.16	252.18	270.51	283.48
Furniture and fixtures	38.7	38.1	38.4	37.2	5.06	5.49	5.91	6.33	195.82	209.17	226.94	234.73
Stone, clay, and glass products	41.5	40.8	40.6	40.0	6.85	7.50	8.27	8.87	284.28	306.00	335.76	354.40
Primary metal industries	41.4	40.1	40.5	38.6	8.98	9.77	0.81	11.34	371.77	391.78	437.81	437.34
Fabricated metal products	40.7	40.4	40.3	39.2	6.85	7.45	8.19	8.78	278.80	300.98	330.06	344.18
Machinery except electrical	41.8	41.0	40.9	39.7	7.32	8.00	8.81	9.28	305.98	328.00	360.33	368.81
Electric and electronic equipment	40.3	39.8	40.0	39.3	6.32	6.94	7.62	8.17	254.70	276.21	304.80	322.65
Transportation equipment	41.1	40.6	40.9	40.5	8.53	9.35	10.39	1.12	350.58	379.61	424.95	450.36
Instruments and related products	40.8	40.5	40.4	39.8	6.17	6.80	7.42	8.26	251.74	275.40	299.77	322.38
Miscellaneous manufacturing industries	38.8	38.7	38.8	38.5	5.03	5.46	5.97	6.41	195.16	211.30	231.64	247.56
Nondurable goods	39.3	39.0	39.1	38.4	6.01	6.55	7.18	7.73	236.19	255.45	280.74	296.83
Overtime hours	3.1	2.8	2.8	2.5	—	—	—	—	—	—	—	—
Food and kindred products	39.9	39.7	39.7	39.4	6.27	6.85	7.44	7.89	250.17	271.95	295.37	310.87
Tobacco manufactures	38.0	38.1	38.8	37.8	6.67	7.74	8.88	9.82	253.46	294.89	344.54	369.68
Textile mill products	40.4	40.1	39.6	37.5	4.66	5.07	5.52	5.83	188.26	203.31	218.59	218.63
Apparel and other textile products	35.3	35.4	35.7	34.7	4.23	4.56	4.97	5.18	149.32	161.42	177.43	180.44
Paper and allied products	42.6	42.2	42.5	41.8	7.13	7.84	8.60	9.32	303.74	330.85	365.50	389.58
Printing and publishing	37.5	37.1	37.3	37.1	6.94	7.53	8.19	8.73	260.25	279.36	305.49	324.63
Chemicals and allied products	41.9	41.5	41.6	40.9	7.60	8.30	9.12	9.98	318.44	344.45	379.39	407.36
Petroleum and coal products	43.8	41.8	43.2	43.9	9.36	0.10	11.38	2.47	409.97	422.18	491.62	546.99
Rubber and miscellaneous plastics products	40.5	40.0	40.3	39.6	5.97	6.52	7.17	7.63	241.79	260.80	288.95	302.94
Leather and leather products	36.5	36.7	36.7	35.6	4.22	4.58	4.99	5.33	154.03	168.09	183.13	189.39
Transportation and public utilities	39.9	39.6	39.4	39.0	8.16	8.87	9.70	0.30	325.58	351.25	382.18	401.70
Wholesale and retail trade	32.6	32.2	32.2	31.9	5.06	5.48	5.92	6.22	164.96	176.46	190.62	198.10
Wholesale trade	38.8	38.5	38.5	38.4	6.39	6.96	7.56	8.06	247.93	267.96	291.06	309.97
Retail trade	30.6	30.2	30.1	29.9	4.53	4.88	5.25	5.49	138.62	147.38	158.03	163.55
Finance, insurance, and real estate	36.2	36.2	36.3	36.2	5.27	5.79	6.31	6.79	190.77	209.60	229.05	245.44
Services	32.7	32.6	32.6	32.6	5.36	5.85	6.41	6.90	175.27	190.71	208.97	224.94

[a]Data relate to production and related workers in mining and manufacturing; to construction workers in construction; and to nonsupervisory workers in transportation and public utilities; wholesale and retail trade; finance, insurance, and real estate; and services.

SOURCE: U.S. Department of Labor, Bureau of Labor Statistics, *Employment & Earnings*, 1984, establishment data, annual averages.

Table 38.—Earnings of Production Workers, Selected Industry Groups, 1936 to Date, Annual Averages

Year	Durable goods industries	Nonelectrical machinery industry	Motor vehicles & equipment industry	Aircraft and parts industry	Metal-working machinery industry	Metal-cutting machinery industry
Average weekly						
1936	$ 23.72	NA	$ 30.13	NA	NA	$ 28.73
1937	26.61	NA	32.66	NA	NA	32.48
1938	23.70	NA	30.59	NA	NA	26.75
1939	26.19	NA	33.58	NA	NA	32.34
1940	28.07	NA	36.69	NA	NA	37.44
1941	33.56	NA	42.68	NA	NA	44.22
1942	42.17	NA	54.15	NA	NA	52.70
1943	48.73	NA	59.13	NA	NA	55.11
1944	51.38	NA	60.12	NA	NA	58.19
1945	48.36	NA	55.28	NA	NA	57.14
1946	46.22	NA	52.28	NA	NA	54.40
1947	51.76	$ 57.58	58.63	$ 54.74	$ 58.69	57.87
1948	56.36	60.38	63.15	60.97	63.13	61.68
1949	57.25	60.31	67.33	63.34	61.33	59.23
1950	62.43	67.08	74.85	68.10	71.73	69.87
1951	68.48	76.13	77.16	77.96	86.01	85.14
1952	72.63	79.55	84.87	81.27	92.20	90.24
1953	76.63	82.68	8988	83.38	96.81	95.17
1954	76.19	81.40	91.30	84.66	93.09	89.25
1955	82.19	87.36	99.84	89.21	98.34	95.48
1956	85.28	93.06	96.82	95.57	108.96	106.25
1957	88.26	94.12	100.61	96.35	106.89	101.04
1958	89.27	94.33	101.24	101.25	102.00	91.20
1959	96.05	102.92	111.38	106.63	113.74	106.93
1960	97.44	104.55	115.21	110.43	117.27	110.99
1961	100.35	107.42	114.65	114.68	117.04	111.92
1962	104.70	113.01	127.67	119.97	125.57	119.41
1963	108.09	116.20	132.68	122.43	128.90	124.42
1964	112..19	121.69	138.03	125.03	137.06	132.01
1965	117.18	127.58	147.63	131.88	144.37	138.76
1966	122..09	135.34	147.23	143.32	153.72	150.20
1967	123.60	135.89	144.84	146.97	154.56	154.25
1968	132.07	141.88	167.66	152.04	158.70	152.65
1969	139.59	152.15	170.56	161.35	172.38	166.61
1970	143.47	154.95	170.47	168.92	174.28	166.00
1971	153.52	161.99	195.29	175.82	174.62	163.90
1972	167.27	179.34	219.22	193.44	198.29	194.71
1973	179.28	193.83	237.08	207.50	214.90	219.11
1974	190.48	207.62	239.54	218.70	225.33	232.74
1975	205.09	219.22	262.68	246.19	226.46	232.68
1976	225.33	236.74	305.30	263.16	248.89	249.96
1977	248.46	259.79	345.40	289.95	279.72	290.18
1978	270.44	285.44	368.05	318.19	308.88	322.56
1979	290.90	305.98	372.37	351.05	329.30	344.21
1980	310.78	328.00	394.00	389.76	346.83	366.21
1981	342.91	360.33	450.31	425.80	371.49	383.95
1982	355.67	367.49	469.80	462.38	377.94	380.83

NA Not Available,

SOURCE U S Bureau of Labor Statistics Employment and Earnings Statistics 190970 (also monthly) National Machine Tool Builders Association 1983-1984 Economic *Handbook of the Machine Tool Industry*

Table 38.— Earnings of Production Workers, Selected Industry Groups, 1936 to Date, Annual Averages—Continued

Year	Durable goods industries	Nonelectrical machinery industry	Motor vehicles & equipment Industry	Aircraft and parts industry	Metal-working machinery industry	Metal-cutting machinery industry
Average hourly						
1936	$ 0.58	NA	$ 0 .76	NA	NA	$ 0.65
1937	0.67	NA	0.88	NA	NA	0.73
1938	0.68	NA	0.91	NA	NA	0.74
1939	0.69	NA	0.92	NA	NA	0.76
1940	0.72	NA	0.94	NA	NA	0.78
1941	0.80	NA	1 .04	NA	NA	0.86
1942	0.94	NA	1 .17	NA	NA	0.99
1943	1 .05	NA	1 .24	NA	NA	1 .09
1944	1. 11	NA	1 .27	NA	NA	1 .15
1945	1. 10	NA	1 .27	NA	NA	1. 19
1946	1 .14	NA	1 .35	NA	NA	1 .27
1947	1 .28	$ 134	1 .47	$ 1.37	$ 1.38	1 .37
1948	1 .40	1 46	1 .61	1 .49	1.49	1 .47
1949	1 .45	1 52	1 .70	1 .56	1 .54	1 .51
1950	1 .52	160	1 .78	1.64	1 .65	1. 62
1951	1 .65	1 75	1 .91	1 .7.8	1 .83	1. 80
1952	1 .75	1 85	2.05	1 .89	1 .97	1 .92
1953	1 .86	1 95	2.14	1 .99	2. 10	2.06
1954	1 .90	200	2.20	2.07	2. 17	2.10
1955	1 .99	208	2.29	2.16	2 .24	2.19
1956	2.08	220	2.35	2.27	2.40	2.33
1957	2.19	229	2.46	2.35	2.48	2.40
1958	2.26	237	2.55	2.50	2.55	2.40
1959	2.36	248	2.71	2.62	2 .67	2.54
1960	2.43	255	2.81	2.70	2 .74	2.63
1961	2.49	262	2.86	2.77	2.80	2.71
1962	2.56	271	2.99	2.87	2.90	2.79
1963	2.63	278	3.10	2.95	2.97	2.88
1964	2.71	287	3.21	3.02	3.08	2.98
1965	2.79	296	3.34	3.14	3.18	3.07
1966	2.90	309	3.44	3.31	3.32	3.23
1967	3.00	319	3.55	3.45	3.45	3.39
1968	3.19	337	3.89	3.62	3.64	3.55
1969	3.38	358	4.10	3.86	3.90	3.83
1970	3.56	377	4.23	4.12	4 .12	4.00
1971	3.80	399	4.74	4.32	4.28	4.16
1972	4.05	427	5.11	4.65	4.59	4.56
1973	4.32	455	5.45	5.00	4. .84	4.88
1974	4.68	492	5.90	5.40	5. 18	5.23
1975	5.14	536	6.47	5.99	5 .51	5.54
1976	5.55	576	7.10	6.45	5.94	5.98
1977	6.06	626	7.85	6.92	6. 49	6.61
1978	6.58	678	8.50	7.54	7. 02	7.20
1979	7.13	732	9.06	8.26	7. 57	7.77
1980	7..75	800	9.85	9.28	8.18	8.38
1981	8.53	881	11 .01	10.31	8.93	9.12
1982	9.05	928	11.60	11 .25	9.52	9.79

NA Not Available

SOURCE U S Bureau of Labor Statistics Employment and Earnings Statistics 190970 (also monthly) National Machine Tool Builders Association 1983-7984 *Economic Handbook of the Machine Tool /ndus/ry*

Table 39.—Average Hourly Earnings in the Machinery Manufacturing Industry,[a] in Selected Areas by Occupation, 1974-75, 1978, 1981

Region and survey year	Occupation: Machine tool operators, production: Class A[b]	Class B[c]	Class C[d]	Numerically controlled	Tool room one type machine	Assemblers: Class A[f]	Class B[g]	Occupation: Inspectors: Class A[h]	Class B	Laborers, material handling	Tool clerks
Baltimore, Md.											
Winter 1974-75	$ 5.17	$4.60	$3.97	$ 5.06	$ 5.21[e]	$4.86	$4.39	$ 5.46	NA	$3.67	$4.07
January 1978	6.74	5.79	5.24	5.67	6.54[e]	6.03	5.71	6.72	NA	5.13	5.38
January 1981	9.01	7.84	7.01	7.68	NA	8.00	6.88	8.88	$7.72	7.21	NA
2. Boston, Mass											
Winter 1974-75	5.04	4.15	3.58	4.66	5.76	4.86	3.97	4.97	4.32	3.66	4.52
January 1978	6.54	6.01	4.71	6.24	6.72	6.18	4.89	NA	5.26	4.56	5.73
January 1981	8.59	8.35	5.87	8.44	NA	8.31	6.62	8.47	7.44	6.18	7.22
3. Buffalo, N.Y.											
Winter 1974-75	5.16	4.78	4.19	5.56	5.43	5.29	4.73	5.54	5.04	4.36	4.43
January 1978	6.77	6.28	5.44	7.00	6.80	6.92	6.43	7.20	6.36	NA	5.86
January 1981	8.97	8.25	7.01	9.47	7.74	9.24	8.07	9.35	7.62	8.11	7.80
4. Chicago, Ill.											
Winter 1974-75	5.71	5.02	4.49	5.59	6.20	5.35	4.58	5.51	5.15	4.30	4.68
January 1978	7.38	6.51	5.90	7.55	8.36	6.84	6.49	7.43	6.80	5.86	6.47
January 1981	9.60	8.00	6.63	9.51	11.31	8.95	7.43	9.25	8.56	6.81	9.10
5. Cleveland, Ohio											
Winter 1974-75	5.68	4.75	3.84	5.68	5.80	5.57	4.95	5.60	5.26	4.49	4.96
January 1978	7.02	6.01	4.12	7.17	7.09	7.21	6.13	7.20	6.65	6.07	6.50
January 1981	9.43	8.13	6.78	9.37	9.66	9.64	7.80	9.93	8.46	8.90	8.86
6. Denver, Colo.											
Winter 1974-75	5.53	4.43	3.78	5.34	5.84[e]	4.90	3.81	5.14	4.03	3.58	4.38
January 1978	6.60	5.36	5.04	6.44	6.63	5.94	4.30	6.67	5.93	4.75	5.89
January 1981	9.30	7.23	NA	8.28	10.69	7.79	5.40	8.55	7.04	5.89	7.54
7. Detroit, Mich.											
Winter 1974-75	6.07	5.46	4.42	6.29	6.68	6.15	5.60	5.74	5.65	4.79	5.44
January 1978	8.19	7.01	5.48	7.14	8.94	7.80	7.23	7.79	6.50	6.94	7.13
January 1981	11.61	9.48	6.21	9.44	12.08	11.17	9.59	11.01	NA	9.45	9.80
8. Houston, Tex.											
Winter 1974-75	5.40	5.01	3.91	5.50	5.31	5.27	4.47	5.43	4.60	4.21	4.65
January 1978	7.15	6.66	4.89	7.29	7.26	6.89	5.86	7.37	6.43	5.38	6.36
January 1981	9.92	NA	5.93	10.08	10.08	9.75	9.06	10.07	8.45	7.41	7.80
9. L.A.-Long Beach Calif.											
Winter 1974-75	5.28	4.56	3.60	5.43	6.17	4.71	3.88	5.38	4.30	3.82	4.58
January 1978	6.87	5.45	3.96	6.86	7.44	6.29	4.41	6.47	5.50	4.67	5.24
January 1981	9.38	7.39	4.83	9.28	9.87	8.02	6.09	9.77	7.20	5.74	6.93
10 Milwaukee, Wis.											
Winter 1974-75	5.75	5.48	5.49	5.48	5.89	5.68	5.24	5.64	5.40	NA	4.77
January 1978	7.78	6.89	NA	7.43	7.86	7.72	6.96	7.24	6.97	6.19	6.28
January 1981	10.47	9.91	8.45	10.36	11.35	10.31	9.09	9.99	NA	8.88	9.13

Table 39.—Average Hourly Earnings in the Machinery Manufacturing Industry,[a] in Selected Areas by Occupation, 1974-75, 1978, 1981—Continued

Region and survey year	Occupation: Machine tool operators, production: Class A[b]	Class B[c]	Class C[d]	Numerically controlled	Tool room one type machine	Occupation: Assemblers: Class A[f]	B[g]	Inspectors: Class A[h]	Class B[i]	Laborers, material handling	Tool clerks
11. Newark, N.J.											
Winter 1974-75	5.31	5.31	3.86	5.61	5.71	5.28	4.21	4.87	4.92	4.02	4.85
January 1978	6.50	6.59	4.85	6.29	7.47	6.54	5.71	5.95	6.61	4.96	5.74
January 1981	9.44	9.04	6.35	7.68	NA	7.93	5.90	7.83	7.77	7.21	6.60
12. Pittsburgh, Pa.											
Winter 1974-75	5.55	5.36	4.97	5.19	5.43	5.80	4.48	6.19	4.99	4.47	4.65
January 1978	7.15	6.71	6.15	6.69	7.21[e]	7.14	6.02	7.37	6.66	5.33	6.18
January 1981	9.44	8.80	8.14	9.33	NA	8.52	7.78	9.44	8.79	8.74	7.48
13. St. Louis, Mo.-Ill.											
Winter 1974-75	6.54	5.07	4.69	6.33	5.76	5.78	4.70	6.23	5.03	4.17	4.62
January 1978	8.25	6.14	6.12	7.26	8.03	6.91	5.81	7.24	6.23	5.11	5.81
January 1981	9.45	8.36	8.30	9.27	8.69	9.10	7.57	9.04	8.35	6.79	7.86

[a]Nonelectrical Machinery (SIC 35).
[b]Operators who set up their own machines and perform a variety of machine operations to close tolerances using decisions based on blueprints and layouts.
[c]Operators who set up their own machines and maintain operation set-ups made by others.
[d]Operators who perform routine and repetitive operations but do not set up machines.
[e]More than one type of machine.

adjusting.
ting of drawings and specifications is involved.

ine Tool Builders Association, *1963-1984 Economic Handbook of the Machine Tool Industry.*

Table 40.– Distribution of Total U.S. Labor Force Among Earnings Classes, 1960 and 1975, and Distribution of 1960-75 Job Increases in the Services

Earnings classes[c]	Distribution of total U.S. labor force (percentages)[a] 1960		1975		1960-1975 job increases in services[b] Numbers of jobs (1,000)	Percentage	
1.60 and above	10,9	31.6	12.0	34.2	1,947	9.5	35.0
1,59 to 1.20	20,7		22.2		5,224	25,5	
1.19 to 0.80	35.9		27.8		2,311	11.3	
0.79 to 0.40	24.1	32.5	28,4	38.0	9,205	44,9	53.8
0,39 and below	8.4		9.6		1,829	8.9	
Total	100.0		100.0		20,516	100,0	

[a]Excludes agriculture, mining, and public administration
[b]Transportation and other utilities wholesale retail finance Insurance, real estate corporate services, consumer services and non profit
[c]Relative to 1 0, for average earnings

SOURCE Thomas M Stanback J r Work Force Trends *The Long Term Impact of Technology on Employment and Unemployment* (Washington D C National Academy Press 1983)

distinctions (e.g., between engineer and technician in some cases) as to raise questions about equal pay for equal work, potentially motivating a compression of the pay scale.

Finally, the factors that shaped past patterns of service sector employment and compensation, such as an accelerating influx of women into the labor force, will not be the ones to shape future traits, especially if capital intensity and productivity grow in the service sector as expected (due to computerization and other factors) and as slower growth in the labor force makes labor scarcer (see below).

Nevertheless, the technologies may also allow a continuing polarization of the work force in at least some instances. For example, a recent study of software production found that individual workers are assigned small pieces of a larger task, which in turn is part of still larger tasks.

> The elaborate division of labor energy in software work is sometimes—and mistakenly—called specialization. It is more accurately called fragmentation. Increasingly, software work is characterized by a stratification of responsibility and pay, not just a division of labor. What is unclear is whether there is a direct path between low-paying and high-paying positions.[77]

A common response, especially from the labor movement, to the prospect of a worsening income distribution (or erosion of earning power) due to changing job opportunities is to propose that work hours be reduced.[78] As Wassily Leontief has noted,

[77]Philip Kraft and Steven Dubnoff, "Software Workers Survey, " *Computer World* (in depth), Nov. 14, 1983.
[78]See, for example: AFL-CIO, "The Future of Work, " mimeo 1983.

> The reduction of the average work week in manufacturing from 67 hours in 1870 to somewhat less than 42 hours must also be recognized as the withdrawal of many millions of working hours from the labor market. Since the end of World War 11, however, the work week has remained almost constant.[79]

Moreover, jobs in manufacturing, especially among metalworking industries, typically include overtime hours of work (and corresponding extra pay). The United Automobile Workers Union has begun to press for reductions in overtime work as a means of increasing auto-industry employment. Its leadership has linked the issues of work hours, job security, and acceptance of technological change.[80] While reducing work hours can increase the number of jobholders, it may not be possible to employ more people without reducing real (i.e., adjusted for inflation) per-person wages. For this reason, job-sharing programs undertaken in Europe and in this country, including reductions in hours of work, have tended to be temporary.

Automation may allow real wages to increase only under certain circumstances, and where they do increase they may not increase enough (see fig. 17). * Increases in nominal as well as real wages will be constrained by increasing international competition. (Note that manufacturing workers in Hong Kong, as in other developing regions, work 6 days a week, 10 hours a day, have few holidays a year and earn relatively low wages. Their lower standard of living constrains us from raising ours where our products compete in the same market.) General Motors, for example, has attempted to increase its ability to compete with producers operating in low-wage countries by introducing a dual pay system which provides lower wages for new workers, confronting existing personnel with "an agonizing choice between going against deeply held union principles and giving some of their neighbors a chance for a job. "[81] Several other companies have also moved to adopt dual pay systems, but such systems are considered controversial.[82] Other mechanisms for sharing work, such as early retirement (which shares jobs between generations rather than among contemporaries), may more easily preserve wage levels, although they may draw on a smaller pool of workers.

Profit-sharing may provide a means by which employees gain job security in exchange for variable compensation. Interest in profit-sharing has been growing recently. Both heightened international competition and greater capital intensity due to PA use may stimulate manufacturers' interest in profit-sharing.

[79] Wassily W. Leontief, "The Distribution of Work and Income, " Scientific American, September 1982. The average of weekly hours in manufacturing during 1982 was 38.9 (down from 40,2 in 1979), compared to 35.1 (down from 35.7 in 1979) for the total private nonfarm economy. See Valerie A. Personick, "The Job Outlook Through 1995: Industry Output and Employment Projections, " *Monthly Labor Review*, November 1983; and U.S. Department of Labor, Bureau of Labor Statistics, Employment and Earnings, May 1983.

[80] "Overtime, Technology, '84, Issues" *Automotive News*, Dec. 19, 1983.

*Note that Leontief has argued that real wages are not likely to rise sufficiently to allow voluntary reductions in the work week, given anticipated technological displacement. Leontief advocates government intervention via income maintenance and income distribution programs. See Wassily N. Leontif, "The Distribut`ion of Work and Income, " op. cit.

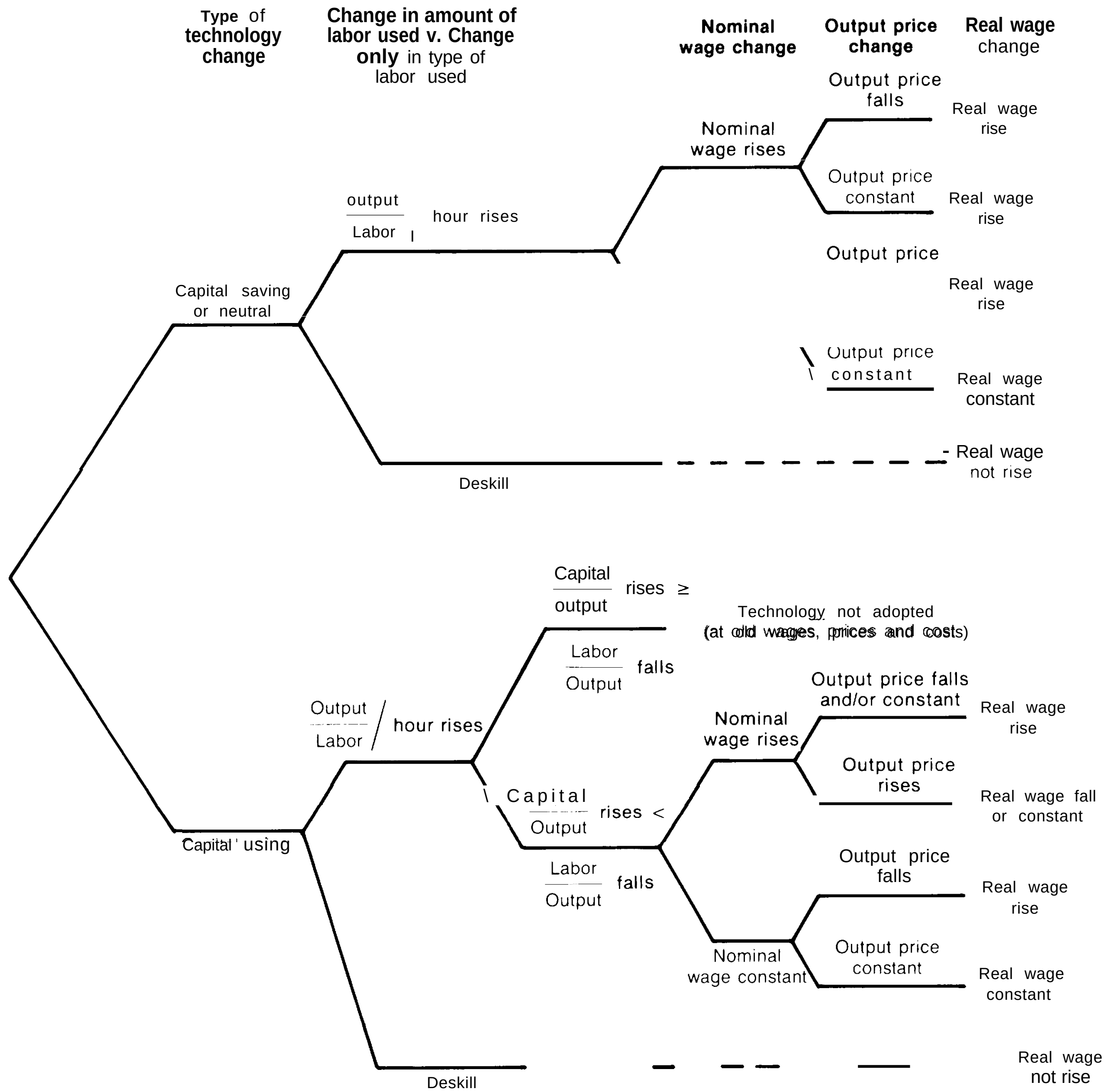
[81] John Holusha, "G. M. Division Votes on Two-Level Pay, " *The New York Times*, Aug. 24, 1983.

[82] Steven Flax, "Pay Cuts Before the Job Even Starts, " *Fortune*, Jan. 9, 1984.

Contextual Factors

There are many ways for companies to adjust to changing labor needs. Employers can lower their use of labor without layoffs or other involuntary separations of employees if: 1) the timing of displacement is paced according to the normal turnover or attrition rate of

Figure 17.—Technology Change and Real Wages



KEY Deslill Reduce hi-skill hi-wage

NOTE There is no straightforward economic analysis of effect of change in skill mix as there is for change in labor productuctivity per se

SOURCE OTA, based on analysis by Eileen Appelbaum, Temple University.

the firm (which reflects resignations, permanent disability departures, deaths, retirements, entry into extended military service, disciplinary discharges, and transfers); 2) current employees who wish to remain with the firm can do new work or jobs (on their own or with training); and/or 3) the level of output expands to at least accommodate the existing labor force, despite growth in output per employee.

AT&T, for example, increased automation without major layoffs during the 1950's and 1960's because of expanding output; it now appears to have less capacity for maintaining employment levels. General Electric, for example, is spending $100 million to modernize refrigerator production and expects to eliminate 1,000 jobs from that operation by the mid-1980's. However, it does not plan to lay off personnel because about 300 employees leave voluntarily each year, and the company plans to reassign personnel to other appliance manufacturing jobs.[83] 84 Similarly, Westinghouse has a policy of not laying off personnel because of technology change.

This section examines relevant changes in the labor supply that may complement the effects of technology and demand changes on hiring patterns, and it examines Japanese approaches to work force adjustment. Chapter 6 discusses retraining and counseling programs to ease transitions of current employees.

Labor Supply

The makeup of the population and the labor force are important factors for evaluating the overall challenge of adjusting to changing job opportunities. The size, growth, and age structure of the labor force are relevant, as is composition by race and sex. OTA expects that some of the labor supply trends discussed below will help to offset the potential negative effects of PA on employment levels.

The total U.S. population is growing relatively slowly; the Census Bureau predicts that the population will reach its maximum size (308.9 million) in the year 2050. Growth in the labor force, which includes principally people between the ages of 16 and 65, peaked during the late 1970's following the influx of the baby-boom generation and rapid growth in labor force activity among women. The median age of the population has risen to over 30, and the proportion of the population under 25 is declining (it is now about 41 percent, down from 46 percent in 1970).[86] The number of persons aged 26 to 29 will also decline through this century. The median age of the labor force is almost 35, and the number and proportion of workers aged 16 to 24—the new entrant group-will fall. Consequently, the labor force is expected to grow relatively slowly in this and future decades (see tables 41 and 42).

Slower growth in the labor force makes the economy better able to absorb increases in output per worker without growth in unemployment. Indeed, for output to grow relative to the labor force, increases in output per worker would be necessary; without them, companies would experience labor shortages. On the other hand, if output does not grow fast enough relative to the labor force, labor surpluses may arise. Labor surpluses may be realized as unemployment, withdrawal from the labor force, or involuntary part-time employment and other forms of underemployment. Official unemployment statistics measure only part of the problem.

The aging of populations and labor forces influences who can and will bear the burden of adjusting to changing labor requirements. Other things being equal, the greater the proportion of older workers, the faster will attri-

[83] Bruce Vernyi, "GE Investing $1OOM in Refrigerator Line," *American Metal Market/Metalworking News*, July 25, 1983.

[84] See "GE to Improve Some Businesses for $590 Million," *The Wall Street Journal, Nov. 2, 1983.* A $362 million investment by GE in plant and equipment for aircraft engines and controls will affect 1,215 employees in two cities. GE plans to reassign many workers, provide "special education and retraining assistance," and sponsor placement programs for personnel choosing to leave.

[85] "U.S. Population Seen Hitting Peak in 2050 of 308.9 Million," *The Wall Street Journal, Nov. 9, 1982;* and H. N. Fullerton, Jr., and J. Tschetter, "The 1995 Labor Force: A Second Look," *Monthly Labor Review*, November 1983.

Table 41.—U.S. Population by Age Groups, 1929-83 (thousands of persons)

July 1	Total	Under 5	5-15	16-19	20-24	25-44	45-64	65 and over
1929	121,767	11734	26800	9,127	10694	35,862	21076	6,474
1933	125579	10,612	26,897	9,302	11,152	37319	22.933	7,363
1939	130880	10,418	25,179	9,822	11,519	39,354	25823	8,764
1940	132,122	10,579	24,811	9,895	11,690	39,868	26,249	9031
1941	133402	10,850	24,516	9,840	11,807	'40,383	26,718	9288
1942	134860	11,301	24,231	9,730	11,955		27,196	9,584
1943	136,739	12,016	24,093	9607	12,064	41,420	27671	9,867
1944	138,397	12,524	23,949	9,561	12,062	42016	28138	10147
1945	139928	12,979	23,907	9,361	12036	42521	28630	10494
1946	141,389	13,244	24,103	9,119	12,004	43027	29064	10,828
1947	144,126	14406	24468	9,097	11,814	43657	29,498	11185
1948	146,631	14919	25,209	8,952	11,794	44288	29931	11538
1949	149,188	15,607	25,852	8,788	11,700	44916	30405	11321
1950	152,271	16,410	26,721	8,542	11,680	45672	30849	12,397
1951	154,878	17333	27279	8,446	11,552	46103	31,362	12,803
1952	157553	17312	28894	8,414	11,350	46495	31,884	13,203
1953	160184	17 638	30227	8,460	11,062	46786	32394	13,617
1954	163,026	18057	31480	8,637	10,832	47001	32,942	14,076
1955	165,931	18566	32,682	8,744	10714	47,194	33,5C6	14525
1956	168,903	19003	33,994	8916	10,616	47,379	34,057	14938
1957	171,984	19,494	35,272	9,195	10603	47440	34591	15388
1958	174,882	19,887	36445	9,543	10,756	47337	35,109	15806
1959	177,830	20,175	37,368	10215	10,969	47,192	35662	16,248
1960	180671	20,341	38,494	10,693	11,134	47,140	36,203	16,675
1961	183691	20,522	39,765	11,025	11,483	47084	36722	17089
1962	186,538	20469	41,205	11,180	11,959	47013	3? 255	17457
1963	189,242	20342	41,626	12,007	12,714	46994	37782	17,778
1964	191889	20,165	42,297	12,736	13,269	46,958	38338	18,127
1965	[illegible]	19,824	42,938	13,516	13,746	46912	38,916	18451
1966	196.560	19,208	43,702	14,311	14050	47001	39,534	18755
1967	[illegible]	18563	44244	14,200	15248	47,194	40,193	19071
1968	200706	17913	44622	14,452	15,786	47721	40846	19, 365
1969	202677	17376	44840	14,800	16,480	48064	41,427	19680
1970	205,052	17166	44,816	15,289	17202	48,473	41999	20107
1971	[illegible]	17244	44,591	15688	18,159	48936	42482	20561
1972	209,896	17101	44203	16,039	18,153	50,482	42,898	21,020
1973	211,909	16,851	43582	16,446	18,521	51,749	43235	21525
1974	213,854	16,487	42,989	16,769	18,975	53051	43,522	22061
1975	215973	16,121	42,508	17017	19,527	54302	43801	22696
1976	218,035	15,617	42099	17,194	19,986	55852	44,008	23,278
1977	220,239	15,564	41298	17276	20499	57,561	44150	23392
1978	222585	15,735	40,428	17,288	20,946	59,400	44,286	24502
1979	225,055	16063	39,552	17,242	21,297	61,379	44390	25134
1980	227704	16,457	38,820	17,136	21612	63,474	44,493	25,714
1981	229,849	16,943	38046	16682	21946	65,496	44,476	26260
1982	232057	17372	37620	16,205	21,935	67,625	44474	26824
1983	234,249							

Note -Includes Armed Forces overseas begtnnlng 1940 Includes Alaska and Hawal beglnmng 1950

SOURCE Department of Commerce Bureau of Census

tion through retirement (normal or early) reduce the population at risk of displacement. However, involuntary retirement is tantamount to layoff, and it may be a source of effective unemployment.

For those eligible for pensions or social security, labor force withdrawal is a more viable alternative to a prolonged job search than it is for younger persons, who are less likely to have alternative sources of income.[86]

[86]Philip L. Rones, "Labor Market Problems of Older Workers," *Monthly Labor Review*, May 1983.

BLS has forecast that the proportion of employees aged 55 and older will fall in the 1980's and 1990's, in part because of anticipated declines in labor force participation.[89] At the same time, there will be growth in the share of 25- to 54-year-old employees, the prime age group. Change in the age mix (and other demographic phenomena, such as labor force participation rates), will also lead to changes in

[87]H. N. Fullerton, Jr., and J. Tschetter, "The 1995 Labor Force: A Second Look," *Monthly Labor Review*, November 1983.

Table 42.—U.S. Population and Labor Force, 1929-83 (monthly data seasonally adjusted, except as noted)

Period	Civilian noninstitutional population[1]	Resident Armed Forces[1]	Labor force including resident Armed Forces	Employment including resident Armed Forces	Civilian labor force: Total	Employment: Total	Employment: Agricultural	Employment: Nonagricultural	Unemployment	Unemployment rate: All workers[2]	Unemployment rate: Civilian workers	Labor force participation rate: Total[3]	Labor force participation rate: Civilian[4]
	Thousands of persons 14 years of age and over									Percent			
1929					149,180	47,630	10450	37,180	1,550		3 2		
1933					51,590	38760	10090	28,670	12,830		24.9		
1939					55,230	45,750	9,610	36,140	9,480		17.2		
1940	99,840				55,640	47520	9,540	37980	8,120		14.6		55 7
1941	99,900				55,910	50350	9100	41250	5,560		9.9		56 0
1942	98,640				56,410	53750	9,250	44500	2,660		4 7		57 2
1943	94,640				55,540	54470	9,080	45,390	1,070		1.9		58 7
1944	93,220				54,630	53,560	8,950	45,010	670		1.2		58 6
1945	94.090				53860	52820	8,580	44240	1,040		19		57.2
1946	103070				57.520	55250	8,320	46933,	2,270		39		55.8
1947	106,018				60,168	57,812	8,256	49557	2,356		39		568
	Thousands of persons 16 years of age and over												
1947	101,827				59,350	57,038	7,890	49,148	2,311		3.9		583
1948	103,068				60,621	58,343	7,629	50,714	2,276		3.8		588
1949	103,994				61,286	57,651	7,658	49,993	3,637		5.9		589
1950	104,995	1,169	63,377	60,087	62,208	58,918	7,160	51,758	3,288	5 2	5.3	59 7	592
1951	104,621	2,143	64,160	62,104	62,017	59,961	6,726	53,235	2,055	3 2	3 3	60 1	593
1952	105,231	2,386	64,524	62,636	62,138	60,250	6,500	53,749	1,883	2.9	3.0	60 0	590
1953[5]	107,056	2,231	65,246	63,410	63,015	61,179	6,260	54,919	1,834	2.8	2.9	59.7	589
1954	108,321	2,142	65,785	62,251	63,643	60,109	6,205	53,904	3,532	5.4	5.5	59 6	588
1955	109,683	2,064	67,087	64,234	65,023	62,170	6,450	55,722	2,852	4.3	4 4	600	593
1956	110,954	1,965	68,517	65,764	66,552	63,799	6,283	57,514	2,750	4 0	4.1	60 7	600
1957	112,265	1,948	68,877	66,019	66,929	64,071	5,947	58,123	2,859	4.2	4 3	60 3	596
1958	113,727	1,847	69,486	64 883	67,639	63,036	5,586	57450	4,602	66	68	60 1	595
1959	115,329	1,788	70,157	66,418	68,369	64,630	5,565	59065	3,740	53	55	59.9	593
1960[5]	117,245	1,861	71489	67,639	69628	65778	5,458	60,318	3,852	5.4	5.5	60.0	59.4
1961	118,771	1,900	72,359	67,646	70,459	65,746	5,200	60,546	4,714	6.5	6.7	60.0	59.3
1962[5]	120,153	2,061	72,675	68,763	70,614	66702	4,944	61,759	3,911	5.4	5.5	59.5	58.8
1963	122,416	2,006	73,839	69,768	71833	67,762	4,687	63,076	4,070	5.5	5.7	59.3	58.7
1964	124,485	2,018	75,109	71,323	73,091	69305	4,523	64,782	3,786	5.0	5.2	59.4	58.7
1965	126,513	1,946	76,401	73,034	74,455	71,088	4,361	66,726	3,366	4.4	4.5	59.5	58.9
1966	128,058	2,122	77,892	75,017	75,770	72,895	3,979	68,915	2,875	3.7	3.8	59.8	59 2
1967	129 874	2,218	79,565	76,590	77,347	74,372	3,844	70,527	2,975	3.7	3.8	60.2	59 5
1968	132,028	2,253	80,990	78,173	78,737	75,920	3,817	72,103	2,817	3.5	3.6	60 3	59.6
1969	134,335	2,238	82,972	80,140	80,734	77,902	3,606	74,296	2,832	3 4	3.5	60.8	60.1
1970	137,085	2,118	84,889	80,796	82,771	78678	3,463	75,215	4,093	4 8	4.9	61.0	60.4
1971	140,216	1,973	86,355	81,340	84,382	79367	3,394	75,972	5,016	5.8	5.9	60.7	60.2
1972[5]	144,126	1,813	88,847	83,966	87034	82153	3,484	78,669	4882	55	5.6	60.9	60 4
1973[5]	147,096	1,774	91,203	86838	89429	85,064	3,470	81,594	4365	48	4.9	61.3	60.8
1974	150,120	1,721	93,670	88,515	91949	86794	3,515	83,279	5,156	55	5.6	61.7	61.3
1975	153,153	1,678	95,453	87,524	93,775	85,846	3,408	82,438	7,929	83	8 5	616	61.2
1976	156,150	1,668	97,826	90,420	96,158	88,752	3,331	85,421	7,406	76	77	620	61.6
1977	159,033	1,656	100,665	93 673	99,009	92,017	3,283	88,734	6991	69	71	626	62.3
1978[5]	161,910	1,631	103,882	97,679	102,251	96,048	3,387	92,661	6,202	60	61	635	63.2
1979	164,863	1,597	106,559	100,421	104,962	98,824	3,347	95477	6137	58	58	640	63.7
1980	167,745	1,604	108 544	100,907	106,940	99,303	3,364	95,938	7,637	7.0	7.1	64.1	63.8
1981	170,130	1,645	110,315	102,042	108,670	100,397	3,368	97 030	8,273	7.5	7.6	64.2	63.9
1982	172,271	1,668	111 872	101 194	110,204	99,526	3,401	96,125	10,678	9.5	9.7	64 3	64 0
1983	174,215	1,676	113,226	102,510	111,550	100,834	3,383	97,450	10,717	9.5	9.6	64 4	64.0

[1] Not seasonally adjusted

[2] Unemployed as percent of labor force including resident Armed Forces

[3] Labor force including resident Armed Forces as percent of noninstitutional population including resident Armed Forces

[4] Civilian labor force as percent or civilian noninstitutional population

[5] Not strictly comparable with earner data due to population adjustments as follows Beginning 1953 Introduction of 1950 census data added about 000000 to popuiat lon and about 350000 to labor force total employment and agricultural employment Beginning 1960, inclusion of Alaska and Hawaii added about 500000 to populat on about 300,000 to labor force, and about 240 000 to nonagricultural employment Beginning 1962, introduction of 1960 census data reduced population b aby about ,000 and labor force and employment bv about 200020 Beginning 1972 introduction of 1970 census data added about 800,000 to civilian noninstitutional population and about 333000 10 labor force and employment A subsequent adjustment based on 1970 census in March 1973 added 60000 to labor force and to employment Beginning 1978 changes in sampling and estimation procedures introduced into the household survey added about 250,000 to labor force and to employment Unemployment levels and rates were not significantly affected

SOURCE Department of Labor, Bureau of Labor Statistics aggregate buying patterns, which will in turn affect production and employment. For example, spending by and for older citizens will grow in absolute terms and relative to spending on child-rearing expenses.

Given the tendency of employers in the United States (and other industrialized nations) to reward seniority by lowering the risk of layoff as tenure rises, the loss of job opportunities associated with programmable automation or business slowdowns first affects younger workers and new job seekers.[88] Many analysts believe that slow growth in the numbers of young adults will lessen competition for manufacturing jobs, lowering the risk of unemployment in manufacturing industries. This may particularly affect durable manufacturing, since workers tend to move out of jobs in those industries as they age. Also, while middle-aged workers are generally not recruited for entry-level jobs, they may begin to fill such jobs in the wake of the decline of younger worker groups. Declining numbers of young workers may also have a favorable effect on unemployment rates generally, since teenagers have accounted for about one-tenth of the population but about one-fourth of cyclical employment variation.[89]

An older labor force means a more experienced work force. Shortages of experienced workers have been cited by employers in the past as a justification for automating. For example, manufacturers have cited the aging and retirement of experienced metalworking craftsmen as a motivation for automating machining operations. On the other hand, new technology, especially rapidly changing technology, may make fresh training more important than experience for some categories of technical personnel. This is believed to be increasingly so for engineers, for exarnple.[90] Skills obsolescence may inhibit the substitution of more available middle-aged and older workers for declining numbers of younger workers, or it may stimulate industrial retraining. An increase in the incidence of unemployment among older workers may raise new concerns. Once displaced, the oldest workers (55 and over) apparently have the longest spells of unemployment, are most likely to suffer pay cuts upon obtaining a new job after being unemployed, and are least likely to change occupations.[91] A major uncertainty is whether and how employers will adapt their personnel practices in response to new technological and demographic conditions.

The contrast between the United States and Japan in rates and extent of adoption of programmable automation reflects in part their differences in population and age structure. The Japanese population aged more quickly than that of the United States (reflecting the lack of a "baby boom" in the postwar years comparable to that in the United States) (see table 43). Since the late 1960's, the Japanese have experienced labor shortages that helped to motivate their adoption of PA. In part, those shortages arose from slow growth in new labor force entrants; in part, they grew out of national norms, including lower female labor force participation, preference for single-shift employment, early mandatory retirement (between 50 and 60), and growing unwillingness of high school graduates to do unpleasant physical work.[92]

Finally, the U.S. labor force w-ill also develop a "new look" due to growing proportions of minority and female workers. Programmable automation may have an important effect on minority employment, in particular, since blacks and Hispanics are now relatively well represented in manufacturing jobs, especially in the lower skilled operative and laborer

[88]See, for example, Robert E. Hall, "The Importance of Lifetime Jobs in the U.S. Economy, " *American Economic Review*, vol. 72(4), September 1982.

[89]U.S. Department of Labor, Office of the Assistant Secretary for Policy, Evaluation, and Research, "The Demographic Composition of Cyclical Variations in Employment, ' Technical Analysis Paper No. 61, January, 1979.

'Douglas Braddock, "Engineers-Higher Than Average Risk of Obsolescence?' *Occupational Outlook Quarterly*. summer 1983,

[91]See Philip L. Rones, "The Labor Market Problems of Older Workers, " and Malcolm H. Morrison, "The Aging of the U.S. Population: Human Resource Implications" both in *Monthly Labor Review*, May 1983.

"See Robert E. Cole, "Participation and Control in Japanese Industry, " paper prepared for Conference on Productivity, Ownership, and Participation, Agency for International Development, U.S. Department of Labor, May 1983; and Kazuo Koike, "Japanese Workers in Large Firms. "

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Table 43.—Japanese Population and Forecast (both sexes) (thousand persons)

(Years of age)	1950	1960	1970	1980	1990	2000	2010	2020	2030	2040	2050
0 ~ 14 (years of age)	29,428	28,067	24,823	27,546	23,327	21,180	22,210	19,402	17,588	17,865	15,960
0 ~ 4	11,205	7,844	8,806	8,564	7,002	7,427	7,162	5,897	6,022	5,816	4,924
5 ~ 9	9,523	9,205	8,159	10,035	7,862	6,823	7,691	6,410	5,724	6,084	5,275
10 ~ 14	8,700	11,018	7,858	8,947	8,463	6,930	7,357	7,095	5,842	5,965	5,761
15 ~ 64 (years of age)	49,658	60,002	71,566	78,790	86,325	86,880	82,942	78,343	75,747	68,578	64,465
15 ~ 19	8,568	9,309	9,064	8,232	10,007	7,847	6,813	7,680	6,402	5,717	6,075
20 ~ 24	7,726	8,318	10,660	7,811	8,913	8,440	6,915	7,342	7,079	5,830	5,952
25 ~ 29	6,185	8,209	9,089	9,073	8,183	9,964	7,819	6,788	7,653	6,378	5,696
30 ~ 34	5,202	7,518	8,372	10,786	7,758	8,868	8,406	6,886	7,312	7,051	5,806
35 ~ 39	5,048	6,038	8,207	9,215	9,002	8,135	9,918	7,782	6,757	7,617	6,349
40 ~ 44	4,483	5,019	7,340	8,322	10,679	7,697	8,808	8,349	6,839	7,262	7,002
45 ~ 49	4,005	4,817	5,878	8,092	9,082	8,897	8,048	9,811	7,699	6,684	7,535
50 ~ 54	3,389	4,201	4,805	7,158	8,132	10,481	7,572	8,663	8,211	6,727	7,142
55 ~ 59	2,749	3,641	4,425	5,632	7,803	8,819	8,651	7,824	9,539	7,458	6,498
60 ~ 64	2,304	2,932	3,726	4,469	6,766	7,732	9,992	7,218	8,256	7,827	6,410
65 and over	4,109	5,350	7,331	10,580	14,609	21,174	26,964	31,029	29,479	29,590	28,872
65 ~ 69	1,771	2,160	2,984	3,939	5,152	7,177	8,151	7,994	7,226	8,811	6,913
70 ~ 74	1,282	1,564	2,134	2,995	3,838	5,894	6,780	8,758	6,327	7,231	6,856
75 ~ 79	686	955	1,268	2,024	2,997	4,088	5,769	6,554	6,425	5,801	7,074
80 ~ 84	276	483	650	1,088	1,823	2,566	4,083	4,694	6,057	4,376	4,994
85 and over	95	188	296	533	799	1,499	2,181	3,029	3,444	3,371	3,035
Grand total	83,200	93,419	103,720	116,916	124,261	129,234	132,116	128,774	122,814	116,022	109,297

SOURCE: Japan Economic Research Center.

categories (see table 44). Minorities may not be well-positioned in the event that manufacturers seek to upgrade educational qualifications, since they are much more likely than whites to have fewer than 12 years of education (see table 45). Also, minorities are disproportionately likely to experience labor market discouragement.[93] Finally, while working women are principally employed in trade and service industries, about 15 percent work in manufacturing. Almost half of female manufacturing personnel are operatives, an occupational category especially susceptible to displacement.[94]

Japanese Mechanisms of Adjustment

Given the great attention now paid to Japanese manufacturing practices and labor management relations, it is useful to examine how Japanese firms have adjusted their work forces with the adoption of automation during periods generally characterized by output growth. Japanese experience reveals that the unique industrial and social stratification practiced there shapes—and to some extent obscures—the incidence of displacement.

Japanese manufacturers who automate often protect their work forces by altering their use of subcontractors and suppliers, transferring personnel, and changing work hours, as well as by increasing output. These are fairly conventional approaches worldwide. However, other Japanese practices are more peculiar to the Japanese context, and are now a source of controversy in Japan, as they would certainly be in the United States. These include the "preferential" laying off of workers such as women, part-time, temporary, and middle-aged and older people.

A recent Japanese survey reported decreased reliance on outside firms and the internalization of more aspects of production, with an accompanying 20 percent or more decrease in women and part-time (mostly female) workers. At the same time, the use of microelectronics technologies had wrought considerable changes for 70 percent of users. Working hours fell (or a second shift was adopted), and on average, production employment fell by 40 percent, with affected personnel being absorbed by transfer to other work.[95] The survey of Japanese electrical machinery workers reported a 60 percent overall decline in staffing caused by microelectronics, affecting peripheral as well as immediate tasks; more often than not, temporary and part-time employment fell first with the introduction of microelectronics.[96] Interestingly, that survey reported that workers perceived a problem of understaffing.

More detailed evidence comes from recent Japanese case studies. In one transistor and integrated circuit plant, before automation, there was one person per machine; after automation the ratio was one to two, production scheduling went from multiple to two shifts, and people were laid off. In a relay-manufacturing plant, the introduction of robots led to a reduction in overtime and the allocation of workers to other tasks elsewhere in the plant. The adoption of an automatic component processing system in an electronic cash register plant resulted in a work force decrease from 100 to 65 (chiefly by laying off women) and the movement of work (20 percent) in-house that was previously performed by subcontractors. Finally, an automobile manufacturer found that robots allowed the direct labor time required in small-car manufacture to decline by about one-half during the 1970's, but output growth allowed employment to rise. However, seasonal and temporary employment fell.[97]

These practices reflect the fact that the vaunted Japanese system of 'permanent employment" is largely limited to male workers

[93] Philip 1.. Rones, "The Labor Market Problems of older Workers, " *Monthly Labor Review*, May 1983.

[94] U.S. Department of Labor, Bureau of Labor Statistics, *Employment and Earnings*, May 1983.

[95] "Ministry of Labor Report on Microelectronics and Its Impact on Labor, " cable from American Embassy (Tokyo) to U.S. Secretary of State, August 1983.

[96] Denki Roren, "Surveys on the Impacts of MicroElectronics and Our Policies Towards Technological Innovation, " paper presented at the 4th IMF World Conference for the Electrical and Electronics Industries, Oct. 3-5, 1983.

[97] "Japan Labor Association, "A Special Study Concerning Technological Innovation and Labor-Management Relations, " Interim Report, June 1983.

Table 44.—Minority Employment Patterns

Emp/eyed black and Hispanic-origin workers by occupation (numbers in thousands)

Occupation	1982 Total employed	Percent of total: Black	Percent of total: Hispanic origin
Total, 16 years and over	99,526	9.2	5.2
White-collar workers	53,470	6.6	3.5
Professional and technical	16,951	6.4	2.6
Health workers	3,263	7.3	2.5
Teachers, except college	3,266	9.0	2.4
Other professional and technical	10,422	5.3	2.7
Managers and administrators, except farm	11,493	3.9	2.9
Salaried workers	9,630	4.0	2.8
Self employed workers in retail trade	838	3.3	4.8
Self employed workers, except retail trade	1,026	3.5	3.1
Sales workers	6,580	3.8	3.3
Retail trade	3,310	4.9	4.3
Other Industries	3,270	2.8	2.3
Clerical workers	18,446	9.4	4.8
Stenographers, typists, and secretaries	4,855	7.5	4.1
Other clerical workers	13,591	10.1	5.1
Blue-collar workers	29,597	10.9	7.5
Craft and kindred workers	12,272	6.7	5.5
Carpenters	1,082	4.2	4.9
Construction craft workers, except carpenters	2,509	8.4	5.4
Mechanics and repairers	3,358	6.2	5.6
Metal craft workers	1,168	7.1	5.6
Blue-collar worker supervisors, not elsewhere classified	1,688	6.7	5.2
Craft and kindred workers—Continued			
All other craft workers	2,467	6.6	6.0
Operatives, except transport	9,429	13.5	10.0
Durable goods manufacturing	3,966	12.5	9,8
Nondurable goods manufacturing	3,054	16.3	11.2
Other industries	2,409	11.5	8.8
Transport equipment operatives	3,377	13.1	6.5
Drivers, motor vehicles	2,921	12.5	6.1
All other	456	17.5	9.2
Nonfarm laborers	4,519	15.1	8.2
Construction	722	16.6	10.7
Manufacturing	880	15.7	8.6
Other industries	2,916	14.6	7.5
Service workers	13,736	16.7	6.3
Private household workers	1,042	28.2	8.2
Service workers, except private household	12,694	15.7	6.2
Food service workers	4,760	10.2	6.4
Protective service workers	1,546	13.8	4.0
All other	6,388	20.4	6.5
Farm workers	2,723	5.5	7.1
Farmers and farm managers	1,452	1.2	.6
Farm laborers and supervisors	1,271	10.4	14.5
Paid workers	1,028	12.7	17.8
Unpaid family workers	244	.4	.4

Employed black and Hispanic-origin workers by industry **(numbers in thousands)**

Industry	1982 Total employed	Percent of total: Black	Percent of total: Hispanic origin
Total, 16 years and over	99,526	9.2	5.2
Agriculture	3,401	5.5	7.4
Mining	1,028	3.0	5.4
Construction	5,756	6.6	5.3
Manufacturing	20,286	9.4	6.5
Durable goods	11,968	8.4	6.1
Lumber and wood products	627	13.7	5.4
Furniture and fixtures	461	6.9	11.9
Stone, clay, and glass products	539	9.5	6.9
Primary metal industries	925	12.1	7.7
Fabricated metal products	1,264	7.2	8.0
Machinery, except electrical equipment	2,558	5.8	4.7
Electrical equipment	2,295	7.4	6.0
Transportation equipment	1,931	11.4	3.4
Automobiles	853	13.7	2.7
Other transportation equipment	1,078	9.6	4.1
Instruments and related products	600	7.2	6.0
Other durable goods industries	768	6.0	9.4
Nondurable goods	8,318	10.8	7.0
Food and kindred products	1,733	10.6	9.6
Textile mill products	688	18.3	4.1
Apparel and other textile products	1,150	13.6	14.9
Paper and allied products	689	10.2	3.9
Printing and publishing	1,621	5.8	3.5
Chemicals and allied products	1,213	11.3	3.6
Rubber and plastics products	643	9.0	7.0
Nondurable goods—Continued			
Other nondurable goods industries	581	12.6	7.1
Transportation and public utilities	6,552	11.0	4.8
Railroads and railway express	469	10.0	3.0
Other transportation	3,121	11.0	5.7
Communications and other public utilities	2,961	11.2	4.1
Wholesale and retail trade	20,758	6.5	5.0
Wholesale trade	4,120	5.4	4.8
Retail trade	16,638	6.8	5.0
Finance, insurance, and real estate	6,270	7.7	4.6
Service industries	30,259	11.4	4.6
Private household	1,271	26.4	7.8
Other service industries	28,988	10.7	4.4
Business repair services	4,452	8.4	5.6
Personal services	2,722	11.3	6.9
Entertainment and recreation services	1,138	6.9	4,6
Professional services	20,507	11.4	3.8
Medical, except hospital	3,518	11.1	3.9
Hospitals	4,341	15.8	3.9
Welfare and religion	1,594	14.6	5.0
Education	8,089	11.1	3.9
Other	2,965	4.5	2.8
Forestry and fisheries	168	4.2	3.6
Public administration	5,218	13.4	4.3

SOURCES U S Department of Labor, *Employment and Earnings* (household data, annual averages), May 1983

Table 45.—Relative Educational Attainment (years of school completed of the civilian labor force by age, sex, and total race: 1980)

United States	Total Male	Total Female	White Male	White Female	Black Male	Black Female	American Indian, Eskimo, and Aleut Male	American Indian, Eskimo, and Aleut Female	Asian and Pacific Islander Male	Asian and Pacific Islander Female	Race, n.e.c. Male	Race, n.e.c. Female
Total, 16 years and over	59,926,488	44,523,329	51,884,626	37,307,269	5,330,792	5,251,644	333,571	250,908	947,280	825,596	1,430,219	887,912
Less than 12 years of school	16,222,652	10,159,951	12,911,874	7,771,259	2,190,803	1,698,293	127,689	81,413	168,430	170,231	823,856	438,755
12 years of school	21,080,014	18,733,366	18,596,168	16,143,347	1,805,410	1,981,651	116,474	99,176	215,261	234,536	346,701	274,656
13 to 15 years of school	10,858,576	8,853,090	9,553,401	7,476,901	871,704	1,018,719	61,129	51,557	193,337	178,275	179,005	127,638
16 years of school	5,961,883	3,928,845	5,514,833	3,450,474	246,877	315,042	13,863	10,349	148,145	127,914	38,165	25,066
17 or more years of school	5,803,363	2,848,077	5,308,350	2,465,288	215,998	237,939	14,416	8,413	222,107	114,640	42,492	21,797
Total, 16 to 19 years	4,327,040	3,821,588	3,723,280	3,299,319	393,790	356,351	29,623	24,531	49,033	45,693	131,314	95,694
Less than 12 years of school	2,744,650	2,049,147	2,326,551	1,755,939	269,180	192,809	20,725	15,077	28,259	23,190	99,935	62,132
12 years of school	1,355,987	1,456,739	1,197,645	1,271,856	108,070	132,581	8,034	8,274	15,202	15,736	27,036	28,292
13 to 15 years of school	225,867	315,190	198,645	271,073	16,494	30,924	855	1,180	5,554	6,743	4,319	5,270
16 years of school	408	466	321	405	46	37	3	—	18	24	20	—
17 or more years of school	128	46	118	46	—	—	6	—	—	—	4	—
Total, 20 to 24 years	8,263,921	7,159,960	6,972,907	5,957,291	835,619	860,510	57,692	44,761	107,197	107,088	290,506	190,310
Less than 12 years of school	1,592,999	802,539	1,180,568	570,260	237,959	147,281	19,134	9,868	13,879	11,483	141,459	63,647
12 years of school	3,792,265	3,219,990	3,259,965	2,708,832	377,032	383,484	26,276	21,503	33,892	31,747	95,100	74,424
13 years to 15 years of school	2,142,726	2,292,112	1,856,557	1,925,094	185,589	266,266	10,742	11,685	43,492	44,454	46,346	44,613
16 years of school	584,405	712,315	538,831	637,534	28,506	53,656	1,059	1,358	10,743	14,047	5,266	5,720
17 or more years of school	151,526	133,004	136,986	115,571	6,533	9,823	481	347	5,191	5,357	2,335	1,906
Total, 25 to 29 years	8,619,669	6,464,535	7,291,610	5,256,841	847,620	864,187	54,739	41,656	145,761	139,224	279,939	162,627
Less than 12 years of school	1,250,521	698,572	893,364	467,608	199,207	147,419	14,092	8,167	15,273	16,889	128,585	58,489
12 years of school	3,195,756	2,531,940	2,711,880	2,056,606	350,632	369,717	22,355	17,858	30,769	31,170	80,120	56,589
13 to 15 years of school	2,094,412	1,591,880	1,793,909	1,298,401	198,268	215,174	13,231	11,242	39,053	35,217	49,951	31,846
16 years of school	1,224,142	1,033,079	1,118,074	903,150	65,500	88,389	2,811	2,734	26,893	29,868	10,864	8,938
17 or more years of school	854,838	609,064	774,383	531,076	34,013	43,488	2,250	1,655	33,773	26,080	10,419	6,765
Total, 30 to 34 years	8,035,553	5,647,299	6,880,960	4,589,364	728,309	751,094	49,304	37,410	162,205	143,625	214,775	125,806
Less than 12 years of school	1,160,683	756,784	843,409	516,412	184,164	155,476	12,053	8,691	14,731	20,557	106,326	55,648
12 years of school	2,579,525	2,331,754	2,206,051	1,925,320	276,010	317,065	17,969	15,367	27,214	32,065	52,281	41,937
13 to 15 years of school	1,870,915	1,252,612	1,620,551	1,021,973	167,960	172,246	13,020	9,207	33,782	30,169	35,602	19,017
16 years of school	1,189,947	676,855	1,090,094	583,029	54,151	56,713	3,116	2,256	33,083	30,647	9,503	4,210
17 or more years of school	1,234,483	629,294	1,120,855	542,630	46,024	49,594	3,146	1,889	53,395	30,187	11,063	4,994
Total, 35 to 39 years	6,334,497	4,574,280	5,466,520	3,778,441	556,144	570,894	38,114	29,153	128,939	105,897	144,780	89,895
Less than 12 years of school	1,229,649	813,962	932,100	579,941	188,021	159,539	12,456	8,590	12,798	17,404	84,274	48,488
12 years of school	2,237,539	2,038,954	1,964,043	1,741,774	206,858	232,939	13,320	11,838	21,303	26,091	32,015	26,312
13 to 15 years of school	1,159,738	874,367	1,019,616	731,276	94,509	108,282	7,808	6,073	20,985	18,511	16,820	10,225
16 years of school	726,653	425,028	663,482	365,752	31,379	34,142	2,036	1,276	25,107	21,624	4,649	2,234
17 or more years of school	980,918	421,969	887,279	359,698	35,377	35,992	2,494	1,376	48,746	22,267	7,022	2,636
Total, 40 to 69 years	23,501,469	16,344,048	20,785,939	3,977,101	1,907,687	,795,396	01,671	71,993	343,572	279,329	362,600	220,229
Less than 12 years of school	7,795,680	4,776,175	6,349,701	3,665,359	1,063,416	855,221	47,536	30,103	76,996	77,862	258,031	147,630
12 years of school	7,758,238	7,023,508	7,104,507	6,317,026	480,805	539,023	28,134	24,102	85,239	96,703	59,553	46,654
13 to 15 years of school	3,271,231	2,461,227	2,974,826	2,167,274	205,631	222,661	15,329	11,993	49,646	42,728	25,799	16,571
16 years of school	2,173,016	1,052,391	2,043,231	933,699	65,767	80,598	4,752	2,717	51,523	31,456	7,743	3,921
17 or more years of school	2,503,304	1,030,747	2,313,674	893,743	92,068	97,893	5,920	3,078	80,168	30,580	11,474	5,453
Total, 70 years and over	844,339	511,619	763,410	448,912	61,623	53,212	2,428	1,404	10,573	4,740	6,305	3,351
Less than 12 years of school	448,470	262,772	386,181	215,740	48,856	40,548	1,693	917	6,494	2,846	5,246	2,721
12 years of school	160,704	130,481	152,077	121,933	6,003	6,842	386	234	1,642	1,024	596	448
13 to 15 years of school	93,687	65,702	89,297	61,810	3,253	3,166	144	177	825	453	168	96
16 years of school	63,312	28,711	60,800	26,905	1,528	1,507	86	8	778	248	120	43
17 or more years of school	78,166	23,953	75,055	22,524	1,983	1,149	119	68	834	169	175	43

n.e.c.—Not elsewhere classified.
SOURCE: Bureau of the Census.

Table 46.—Employed Persons and Employees by Occupation, Japan (ten thousand persons)

Year	Total	Professional and technical workers	Managers and officials	Clerical and related workers	Sales workers	Farmers, lumber-men, and fisher-men	Mining workers	Workers in transport and commu-nication occupations	Craftsmen and production process workers	Labourers	Protective service workers and service workers
Employed persons:											
Both sexes: Annual average:											
1975	5,223	364	206	820	738	654	9	237	1,580	148	457
1976	5,271	380	215	828	754	634	10	242	1,589	151	457
1977	5,342	389	212	850	778	625	10	238	1,603	159	465
1978	5,408	399	204	871	791	626	7	243	1,611	160	486
1979	5,479	426	217	898	784	605	5	244	1,628	164	497
1980	5,536	438	220	924	797	570	5	248	1,653	168	501
1981	5,581	452	228	945	811	552	5	238	1,659	207	473
1982	5,638	471	220	973	838	543	4	237	1,648	210	480
Change *over the year:*											
1976	48	16	9	8	16	-20	1	5	9	3	0
1977	71	9	-3	22	24	-9	0	-4	14	8	8
1978	66	10	-8	21	13	1	-3	5	8	1	21
1979	71	27	13	27	-7	-21	-2	1	17	4	11
1980	57	12	3	26	13	-35	0	4	25	4	4
1981	45	14	8	21	14	-18	0	-10	6	39[b]	-28[b]
1982	57	19	-8	28	27	-9	-1	-1	-11	3	7
Change over the year:											
1976	0.9	4.4	4.4	1,0	2.2	-3.1	·	2.1	06	2.0	0.0
1977	1.3	2.4	-1.4	2.7	3.2	-1.4	0.0	-1.7	0.9	5.3	1.8
1978	1.2	2.6	-3.8	2.5	1.7	0.2	-30.0*	2.1	0.5	0.6	4.5
1979	1.3	6.8	6.4	3.1	-0.9	-3.4		0.4	1.1	2.5	2.3
1980	1,0	2.8	1.4	2.9	1.7	-5.8	:	1.6	1,5	2.4	0.8
1981	0.8	32	3.6	2.3	1.8	-3.2	"	-4,0	0.4	23.2[b]	-5.6[b]
1982	1.0	4.2	-3.5	3.0	3.3	-1.6		-0.4	-0.7	14	1,5
Percentage distribution											
Both sexes: **Annual average:**											
1975	100.0	7.0	3.9	157	14,1	12.5	0.2	4.5	303	2.8	8.7
1976	100.0	7.2	4.1	15.7	14,3	12.0	0.2	4.6	30.1	2.9	8.7
1977	100.0	7.3	4.0	159	14.6	11.7	0.2	4,5	30.0	3.0	8.7
1978	100.0	7,4	3.8	16.1	14.6	11.6	0.1	4,5	29.8	3.0	9.0
1979	100.0	7.8	4,0	16.4	14.3	11.0	0.1	4.5	29.7	3.0	9.1
1980	100.0	7.9	4.0	16.7	14.4	10.3	0.1	4,5	29.9	3.0	9.0
1981	100.0	8.1	4.1	16.9	14.5	9.9	0.1	4.3	29.7	3.7	8.5
1982	100.0	84	3.9	17.3	14.9	9.6	0.1	4.2	29.2	3.7	8.5
Male: **Change** *over the year:*											
1975	1000	6.3	6.0	12.4	14,0	10.0	0.3	6.7	34.9	2.9	6.3
1976	100.0	6.6	6.2	12.2	14.3	9.7	0.3	6.8	34.5	2.8	6.3
1977	100,0	6,6	6.1	12.2	14.6	9.6	0.3	6.7	34,4	3.0	6.2
1978	100.0	6.6	5.8	12.5	14.6	9.6	0.2	6.9	34,3	2.9	6.5
1979	100,0	6.7	6.1	12.6	14.3	9.1	0.1	6,8	34,3	2.9	6.7
1980	100.0	6.9	6,2	12.6	14.4	8.5	0.1	6.9	34.4	2.9	6.7
1981	100.0	7.1	6.3	12.7	146	8.4	0.1	6.6	34.2	3.5	6.3
1982	100.0	7.4	6.1	12.9	15.0	8.1	0.1	6.5	33.9	3.4	6.3
Female: Change over the year:											
1975	100.0	8.0	0.6	21.2	14,4	16.8	0.0	0.9	22.4	2,7	12.8
1976	100.0	8.2	0.6	21.6	14,3	15.9	0.0	0.9	22,9	2.9	12,6
1977	100.0	8.4	0.5	22.0	14.5	15.1	0.0	0,8	22,8	2.9	12,7
1978	100,0	8.7	0.5	21.9	14.7	14,8	0.0	0.7	22.7	3.0	12.9
1979	100.0	9.4	0.6	22.3	14.3	14.2	0.0	0.8	22,3	3.1	12,8
1980	100,0	9.6	0.5	23.1	14.3	13.1	0,0	0.7	22.6	3.1	12,7
1981	100.0	9.7	0.6	23,6	14.4	12,3	0.0	0.6	22.7	4.1	11.8
1982	100.0	9.8	0.5	24.0	14.6	12.0	0.0	0.6	22.0	4.3	12.0

[a]The Occupational Classifications for the Labour Force Survey were revised in January 1981 to correspond to the Occupational Classifications used in the 1980 Population Census "Workers in mining and quarrying occupations" have been reclassified as "Mining workers, " and "Sweepers and garbage men, previously listed as "Protective service and service workers" are classified as "Labourers" in the current survey

[b]As of January 1981, there were 320,000 "Sweepers and garbage men, " 100,000 male and 230,000 female,
Take the above explanation into consideration when the difference or percentage for year. to-year change of monthly estimates are used

SOURCE "Annual Report of the Labour Force Survey, ' Statistics Bureau, Off Ice of the Prime Minister, Japan, 1982

Table 46.—Employed Persons and Employees by Occupation, Japan (ten thousand persons) —Continued

Year	Total	Professional and technical workers	Managers and officials	Clerical and related workers	Sales workers	Farmers, lumber-men, and fisher. men	Mining workers	Workers in transport and commu-nication occupations	Craftsmen and production process workers	Labourers	Protective service workers and service workers
Employees:											
Both sexes: Annual average:											
1975	3,646	304	205	775	427	41	9	220	1,216	132	315
1976	3,712	316	214	783	448	41	9	225	1,224	135	315
1977	3,769	322	211	803	463	43	10	222	1,235	140	317
1978	3,799	329	201	818	470	40	7	226	1,233	141	331
1979	3,876	352	215	844	476	38	5	226	1,237	144	336
1980	3,971	364	217	867	497	40	4	229	1,260	148	342
1981	4,037	377	226	886	506	43	4	220	1,272	184	317
1982	4,098	394	217	909	537	41	4	220	1,269	187	315
Change over the year:											
1976	66	12	9	8	21	0	0	5	8	3	0
1977	57	6	-3	20	15	2	1	-3	11	5	2
1978	30	7	-10	15	7	-3	-3	4	-2	1	14
1979	77	23	14	26	6	-2	-2	0	4	3	5
1980	95	12	2	23	21	2	-1	3	23	4	6
1981	66	13	9	19	9	3	0	-9	12	36[b]	25b
1982	61	17	-9	23	31	-2	0	0	-3	3	-2
Change over the year (%):											
1976	1.8	3.9	44	10	49	00	*	23	07	23	00
1977	1.5	1.9	-1.4	26	33	4.9	.	-1.3	0.9	3.7	0.6
1978	0.8	2.2	-47	19	1.5	-7.0	-30.0	1.8	-0.2	07	4.4
1979	2.0	7.0	7.0	32	1.3	-5.0	.	00	0.3	2.1	1.5
1980	2.5	3.4	09	27	4.4	5,3	.	1.3	19	28	18
1981	1.7	3.6	4.1	22	1.8	7.5	.	-3.9	10	24.3[b]	7.3[b]
1982	1.5	4.5	-40	26	61	–4.7	.	00	-02	16	-06
Percentage distribution											
Both sexes: Change over the year (%):											
1975	1000	8.3	56	21.3	117	11	02	60	334	3.6	8.6
1976	100.0	8.5	58	21.1	121	1.1	02	61	330	3.6	8.5
1977	1000	85	56	21.3	123	11	0,3	59	328	37	8.4
1978	1000	8.7	53	21.5	124	1.1	02	59	32.5	3.7	8.7
1979	1000	9.1	55	21.8	123	10	01	5.8	31.9	37	8.7
1980	100.0	92	55	21.8	125	1.0	01	5.8	31.7	37	86
1981	100.0	93	56	21.9	125	11	01	5.4	31.5	4.6	79
1982	1000	96	53	22.2	131	10	01	5.4	31.0	4.6	7.7
Male:											
1975	1000	68	78	16.1	12.1	13	0.4	82	37.5	3.5	6.3
1976	1000	71	8.1	15.8	12.5	13	04	8.3	36.9	35	6.2
1977	1000	70	7.9	15.8	129	1.3	04	82	367	37	60
1978	1000	69	7.6	16.3	128	1.2	0.3	8.4	36.5	3.6	64
1979	1000	71	80	16.3	12.8	1.1	0.2	8.2	36.4	3.5	64
1980	1000	7.2	79	16.2	13.0	1,1	0.2	82	36.1	36	64
1981	1000	74	81	16.2	130	1.3	0.2	78	35.8	42	60
1982	1000	77	76	16.4	137	1.2	0.1	77	35.6	4.0	5.8
Female:											
1975	1000	116	09	32.2	11.1	0.8	0.0	1.5	24.6	37	13.7
1976	100.0	115	10	32.2	11.1	0.7	0.0	1.4	249	40	13.3
1977	100.0	117	09	32.4	11.1	0.7	0.0	1,2	248	38	133
1978	1000	12.2	07	32.0	11.6	0.7	0.0	1.1	24.5	39	13.4
1979	1000	13.1	08	32.4	11.4	0.7	0.0	1.2	23.3	4.0	13.1
1980	100.0	130	0.8	32.7	11.6	0.7	00	1,0	23.2	40	12,9
1981	1000	131	09	32.9	11.6	0.6	00	0.9	23.3	5.3	114
1982	100.0	132	08	33.2	11.9	0.7	0.0	0.9	22.4	5.6	112

[a]The Occupational Classifications for the Labour Force Survey were revised in January 1981 to correspond to the Occupational Classifications used in the 1980 Population Census Workers in mining and quarrying occupations" have been reclassified as "Mining workers," and "Sweepers and garbage men" previously listed as 'Protective service and service workers" are classified as " Labourers" in the current survey

[b]As of January 1981, there were 320,000 "Sweepers and garbage men, " 100,000 male and 230,000 female.

Take the above explanation into consideration when the difference or percentage for year-to-year change of monthly estimates are used

NOTE Employees are the subset of employed persons that is not self-employed

SOURCE Annual Report of the Labour Force Survey, " Statistics Bureau, Off Ice of the Prime Minister Japan, 1982 in large firms.[98] Because of that system, nonetheless, Japanese employers are less free than U.S. employers to lay off personnel. They have an incentive to minimize hiring of "regular" employees, and to increase use of others whose ranks can more easily be cut (see tables 46 and 47).

Note that U.S. employers have increasingly resorted to the use of temporary personnel. The temporary-help service industry in the United States has been growing, and the proportion of temporaries comprised of such professionals as engineers, scientists, and technicians has also been growing. (Statistics are not available to show trends for manufacturing industries alone.) As noted by the National Association of Temporary Services:

> By hiring temporaries, companies can cut staff without layoffs. They can hire temporaries for short-term projects too large or too specialized for their permanent staff to handle.[99]

Because adopting PA raises companies' fixed costs, many of them might seek to increase reliance on temporaries or part-time personnel, where feasible, to lessen their vulnerability to downturns.

[98]See Robert E. Cole, "Participation and Control in Japanese Industry, " paper prepared for Conference on Productivity, Ownership, and Participation, Agency for International Development, U.S. Department of Labor, May 1983.

'Sam Sacco, "The World of High-Tech Temporaries, " Washington *Post* (Advertising Supplement), Apr. 24, 1983.

Table 47.—Employed Persons by Industry and Status in Employment, Japan
(for employees, number of persons engaged in enterprise) (1982)

Industry	Total	Employees: 1-29 persons: Total	1-4 persons	5-29 persons	30 persons and over: Total	30-99 persons	100-499 persons	500 persons and over: Total	500-999 persons	1,000 persons and over	Government employees
Both sexes											
1)	4098	1,408	339	1,069	2,184	632	591	962	184	778	498
2)	30	18	7	11	6	3	2	1			6
3)	16	12	5	7	3	2	1		—		1
4)	14	6	2	5	3	2	1				5
5)	4,068	1,390	332	1,058	2,178	628	589	961	183	777	492
6)	14	8	1	7	6	3	2	1	—	1	
7)	10	3	—	3	6	2	1	3		3	—
8)	423	257	56	201	164	78	38	48	10	38	
9)	1,151	324	46	278	825	220	226	378	77	301	1
10)	125	48	7	40	77	33	28	17	5	12	
11)	147	29	4	26	117	25	29	64	13	51	
12)	557	120	16	103	437	91	106	239	42	197	—
13)	66	8	1	7	58	7	11	40	4	36	
14)	103	49	8	40	54	24	17	13	5	8	
15)	131	31	4	27	100	25	29	46	12	35	—
16)	158	21	2	19	137	25	34	78	12	66	
17)	99	11	1	10	88	10	16	61	8	53	
18)	322	127	19	108	194	71	64	59	17	42	1
19)	1,059	470	146	324	583	150	149	284	55	229	5
20)	870	443	135	309	423	139	126	159	42	117	3
21)	337	138	25	114	198	73	62	63	19	45	—
22)	534	305	110	195	225	66	63	96	23	72	3
23)	128	95	37	58	32	16	9	7	2	5	
24)	189	27	12	15	160	11	23	125	12	113	2
25)	364	51	4	47	263	47	53	163	16	148	50
26)	331	51	4	46	240	46	51	142	15	127	39
27)	34		—	—	23	1	1	21	—	20	11
28)	847	276	77	199	329	127	119	83	25	57	241
29)	427	112	31	82	120	48	46	26	9	17	194
30)	420	163	45	118	209	79	73	57	17	40	47
31)	195		—		—	—	—				195
Percent male											
1)	65.40	60.30	55.75	61.74	58.09	63.13	65.82	72.66	71 20	73.01	6787
9)	65.94	58.02	63.04	57.19	69.09	56.76	63.87	79.37	7273	8106	10000
12)	73.25	68.33	75.00	66.99	74.60	63.74	67.92	81.59	73.81	8325	
14)	75.73	75.51	87.50	75.00	75.93	70.83	76.47	84.62	8000	8750	—
15)	77.10	74.19	75.00	74.07	78.00	76.00	72.41	82.61	7500	8286	
16)	59.96	42.86	50.00	36.84	59.85	41.67	52.94	71.79	58.33	7273	—
17)	80.81	63.64	100.00	70.00	82.95	70.00	75.00	88.52	8750	8868	
Percent female											
1)	34.60	39.70	44.25	38.26	31.91	36.87	34.18	27.23	28.80	26.99	32.13
9)	34.06	41.98	39.13	42.45	31.03	42.34	36.73	20.63	27.27	19.27	100.00
12)	26.75	31.67	25.00	33.01	25.40	36.26	32.08	78.41	26.19	16.75	—
14)	23.30	24.49	25.00	25.00	22.22	25.00	25.53	15.38	20.00	12.50	—
15)	23.66	25.81	25.00	25.93	22.00	24.00	27.59	17.39	16.67	17.14	—
16)	43.04	57.14	50.00	57.89	40.88	62.50	47.06	29.49	41.67	27.27	—
17)	18.18	36.36	—	40.00	15.91	30.00	25.00	11.48	25.00	11.32	—

1) All industries
2) Agriculture and forestry
3) Agriculture
4) Forestry and hunting
5) Nonagricultural industires
6) Fisheries and aquaculture
7) Mining
8) Construction
9) Manufacturing
10) Textile mill products
11) Chemical and related products
12) Metal and machinery
13) Iron, steel and non-ferrous metal industries
14) Fabricated metal products
15) Machinery, weapons, and precision machine
16) Electrical machinery, equipment and supplies
17) Transportation equipment
18) Other manufacturing
19) Wholesale, retail trade, finance, insurance and real estate
20) Wholesale and retail trade
21) Wholesale trade
22) Retail trade
23) of which Eating and drinking place
24) Finance, insurance and real estate
25) Transport, communication, electricity, gas, water, steam and hot water supply
26) Transport and communication
27) Electricity, gas, water, steam and hot water supply
28) Services
29) Professional services
30) Other services
31) Government

SOURCE: "Annual Report of the Labour Force Survey," Statistics Bureau, Office of the Prime Minister, Japan, 1983.

Table 47.—Employed Persons by Industry and Status in Employment, Japan—Continued (for employees, number of persons engaged in enterprise) (1982)

		Self. employed workers				Employees (regrouped)					
							Regular employees				
Industry	Total	Total	With employees	Without employees	Family workers	Total	Total	Ordinary regular employees	Directors	Temporary employees	Day labourers
Both sexes											
1)	5,638	943	193	750	587	4,098	3,692	3,399	294	278	127
2)	502	240	7	234	232	30	20	18	2	3	6
3)	484	237	6	232	231	16	10	9	1	2	3
4)	18	3	1	2	1	14	10	10	—	1	3
5)	5,136	702	186	516	355	4,068	3,672	3,380	292	275	121
6)	46	18	2	16	13	14	13	12	1	1	1
7)	10	—	—	—	—	10	9	9	1	—	—
8)	541	88	37	51	31	423	346	299	47	25	51
9)	1,380	161	29	132	68	1,151	1,053	978	75	75	24
10)	208	65	5	60	18	125	110	101	9	11	5
11)	166	13	2	10	6	147	138	131	7	7	2
12)	614	40	10	30	17	557	520	490	31	29	7
13)	67	1	—	—	1	66	64	62	3	1	—
14)	127	16	5	10	9	103	95	85	11	5	2
15)	143	8	2	5	4	131	125	115	10	6	1
16)	175	15	2	13	2	158	142	137	5	13	3
17)	102	1	1	1	1	99	94	91	3	4	1
18)	392	44	12	32	26	322	284	257	28	29	9
19)	1,501	258	77	181	183	1,059	948	830	118	90	22
20)	1,296	246	75	171	179	870	765	659	106	84	21
22)	376	24	8	16	16	337	323	278	45	10	4
22)	919	222	67	155	163	534	442	381	61	74	18
23)	237	67	33	34	41	128	95	85	10	26	7
24)	206	13	2	11	4	189	183	171	12	5	—
25)	382	15	2	12	3	364	350	339	11	11	3
26)	349	15	2	12	3	331	317	306	11	10	3
27)	34	—	—	—	—	34	33	32	—	1	—
28)	1,065	162	39	123	56	847	767	727	39	64	16
29)	510	66	19	46	17	427	396	381	14	27	4
30)	554	96	19	77	39	420	371	346	25	37	12
31)	195	—	—	—	—	195	184	184	—	8	3
Percent male											
1)	60.98	68,61	82.9	64.93	17,55	69.40	68,82	6781	79,93	26.98	50.39
9)	61.23	45.96	96.55	34.85	17.65	65.94	70.18	69.33	82.67	18.67	25.00
1 2)	7068	57.50	100.00	43.33	23.53	73.25	76.92	76.12	83.87	20.69	2857
14)	73.23	75.00	100.00	7000	22.22	75.73	78.95	77.65	81.82	40.00	5000
1 5)	74.83	62.50	100.00	60.00	25.00	77.10	79.20	79.13	80.00	16.67	
16)	53.14	20.00	100.00	92.31	–	56.96	62.68	61.31	80.00	7.69	
17)	80.39	10000	100.00	10000	—	80.81	84.04	83.52	100.00	25.00	
Percent female											
1)	39.03	31.39	16.58	35.07	82.28	34.60	31.20	32.16	20.07	73.02	49.61
9)	38,77	54.04	3.45	65.15	82.35	34,06	29.72	30.67	17.33	81.33	75.00
12)	2915	42,50	–	56,66	82.35	26.75	23,27	23.67	16,13	79,31	71.43
14)	26.77	18.70	–	30.00	77.78	23.30	21,05	21.18	18,18	60,00	50.00
15)	25.17	25.00	—	40,00	100.00	23.66	20.00	20.87	10.00	66.67	100.00
16)	4629	80.00	—	7.69	100.00	43.04	37.32	38.69	20.00	92.31	66.67
1 7)	18.63	—	—	—	100.00	18.18	15.96	16.48	—	75.00	100.00

1) All industries
2) Agriculture and forestry
3) Agriculture
4) Forestry and hunting
5) Nonagriculture industries
6) Fisheries and aquiculture
7) Mining
8) Construct Ion
9) Manufacturing
10) Textile mill products
11) Chemical and related products
12) Metal and machinery
13) Iron, steel and nonferrous metal industries
14) Fabricated metal products
15) Machinery, weapons, and precision machine
16) Electrical machinery, equipment and supplies
17) Transportation equipment
18) Other manufacturing
19) Wholesale, retail trade, finance, insurance and real estate
20) Wholesale and retail trade
21) Wholesale trade
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26) Transport and communication
27) Electricity, gas, water, steam and hot water supply
28) Services
29) Professional services
30) Other services
31) Government

SOURCE ‘Annual Report of the Labour Force Survey, ” Statistics Bureau, Off Ice of the Prime Mlnlster, Japan, 1983