Chapter 2

Labor Markets and Working Environment

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INTRODUCTION

The use of computers in manufacturing has aroused concern since the late 1950's and early 1960's, when awareness of the potential of computer technology began to emerge and when applications of more conventional automated manufacturing were accelerating. During that period public interest in the social ramifications of automation and computers was greater in Europe than in the United States. However, official U.S. concern led to the formation in 1965 of a special Federal study commission, the National Commission on Technology, Automation, and Economic Progress, charged with the tasks of: 1) assessing the effects, role, and pace of technological change; 2) describing changes in employment demands and working conditions associated with technological change; 3) defining "unmet community and human needs" that technology can help to meet; and 4) identifying policy options for implementing new technologies. After meeting for a year, the Commission issued a report that foreshadows contemporary discussions of job displacement, changing working conditions, and instructional needs.

From the 1950's through today, labor-related concerns associated with automation and computers have tended to fall into three not-wholly-distinct categories: 1) labor markets or employment, 2) working environment (job content and occupational safety and health), and 3) industrial or labor-management relations. Of these three categories, labor market issues have been most salient in popular (and political) discussions of automation, because employment is widely seen as reflecting the economic vitality of a country or region. By contrast, working environment issues may be more subtle and more likely to be appreciated by those groups of people in direct contact with specific working environments. Finally, industrial relations both influence and are influenced by changes in labor markets and working environments that are associated with new technology and other factors.

In order to analyze the labor market implications of programmable automation, it is necessary to be able to measure and forecast the degree and types of changes in employment that may accompany the spread of this technology. The variety of claims as to the eventual employment impacts of programmable automation that are being publicized by the media suggests that such evaluations are straightforward. However, there appears to be no accepted methodology for making such employment forecasts reliably, a problem that was emphasized in debates among participants of the OTA Labor Markets and Industrial Relations Workshop. This technical memorandum points out some of the shortcomings of many publicized forecasts and some of the requirements for satisfactory forecasts.

POTENTIAL FOR OCCUPATIONAL CHANGE: AN OVERVIEW

A first step in measuring or forecasting how programmable automation *or* other new technologies may affect employment-by occupation and industry-is to assess: 1) how programmable automation affects the activities performed by people working in user industries and occupations, and 2) what types of activities maybe performed by people engaged in producing automated equipment and systems. Unfortunately, there are few empirical data describing relevant activities. Moreover, what data may exist (e.g., in case studies) may have little general value because early programmable automation applications have been limited in number compared to applications of other types of equipment and systems, and they have been tailored to individual company needs. Early applications also are likely to be different from later applications involving more sophisticated equipment and systems, especially since future applications are expected to feature greater computer integration of production and other company activities.

At this time it appears that the range of activities undertaken by manufacturing firms and vulnerable to change in connection with programmable automation is not limited to the fabrication and assembly of products. Employment that may be directly affected by the production and use of programmable automation is associated with a wide range of activities, including research and development; the design, fabrication, assembly, distribution, and servicing of products; and management.

Production Activities.—The types of new activities associated with production of programmable automation, as compared with production of conventional factory equipment, are those that pertain to its computerization aspects, namely the development, distribution, and/or adaptation of computer hardware and software. Computerization, or more broadly a shift to microelectronics from mechanical or electromechanical components, may also alter other activities associated with production of programmable automation. For example, the use of microelectronic components affects fabrication and assembly techniques, in part because individual microelectronic components can often do the work of multiple mechanical ones.[1] Finally, like the production of conventional equipment, production of programmable automation also entails applications engineering, technical support, installation, sales, and clerical activities.

Use Activities.—Activities associated with the use of programmable automation are broadly similar to those associated with the production of programmable automation, since both production and use of programmable automation are manufacturing endeavors. Nevertheless, variation among user industries (including users who also produce programmable automation) by size and by nature of product will determine the specific types of tasks and occupations affected among users. The types of tasks that maybe created with the use of programmable automation also pertain to computerization (e.g., programing, maintenance of electronic equipment, and data base management). The types of tasks that may be eliminated are those tasks sensitive to the internalization of information flows (e.g., for certain clerical operating and supervisory tasks), or to the replacement of physical labor (e.g., for welding, assembling, materials handling, and drafting).

[1] Roy Rothwell and Walter Zegveld, *Technical Change and Employment (New* York: St. Martin's Press, 1979).

OCCUPATIONAL CHANGE FORECASTING

Historically, attempts to forecast detailed changes in occupational employment have met with limited success. As the Bureau of Labor Statistics (BLS) has noted in evaluating its own forecasts, it is easier to predict directions of change for broad categories of employees than magnitudes of change for relatively specific groups. This situation is unfortunate, since the more detailed the occupational differentiation, the more precise may be the evaluation of employment variation among occupations and industries and therefore the identification of people who may benefit or be harmed by technological change.[2]

The occupations of people who maybe directly affected by the spread of programmable automation include professional specialty; executive, administrative, and managerial; technicians and related support; machine operators, assemblers, and inspectors; precision production, craft, and repair; and handlers, equipment cleaners, helpers, and laborers. Table 1 contains the full current and prior lists of major census occupational groups. While this set of categories can be used to describe the occupational mix of any industry and the labor force as a whole, it is too broad to describe more than gross shifts in oc-

'Max L. Carey and Kevin Kasunic, "Evaluating the 1980 Projections of Occupational Employment, "*Monthly Labor Review,* July 1982.

Note that in practice, very detailed occupational analyses may be less accurate than more aggregated analyses because of nonsampling errors in occupational title classification and analysis. See Harvey Goldstein, "Occupational Employment Projections for Labor Market Areas: An Analysis of Alternative Approaches" (Washington D. C.: U.S. Department of Labor, 1981), R&D Monograph 80.

Table 1.—A Comparison of 1980 and 1970 Decennial Census Occupational Categories

1980	*1970*
Broadest groupings	
Managerial and professional specialty	White-collar
Technical, sales, and administrative support	Blue-collar
Service	Service
Precision production, craft, and repair	Farm
Operators, fabricators, and laborers	
Farming, forestry, and fishing	
Major occupational groups	
Executive, administrative, and managerial	Professional and technical
Professional specialty	Managers and administrators, except farm
Technicians and related support	Sales
Sales	Clerical
Administrative support, including clerical	Craft and kindred
Private household	Operatives, except transport
Protective service	Nonfarm laborers
Service, except private household and protective service	Private household
Precision production, craft, and repair	Other service workers
Machine operators, assemblers, and inspectors	Farmers and farm managers
Transportation and material moving	Farm laborers and supervisors
Handlers, equipment cleaners, helpers, and laborers	
Farming, forestry, and fishing	

SOURCE: John E. Bregger, "Labor Force Data From CPS to Undergo Revision in January 1983, *Monthly Labor Review,* November 1982.

cupational proportions. Within each category, hundreds of occupations can be differentiated. Aggregating occupational categories may result in uncertainty about future change in such detailed occupations as "robot technician, " where the specific designation falls within a broader category, such as science and engineering technicians. Another cost of aggregation is generality—the average pattern of change within an industry may not correspond to actual changes experienced by individual companies or people, in part because individual companies vary in their use of employees with very specific skills, as well as in their use of production technologies. However, even a detailed occupational breakdown may mask changes in job content that may arise with new technology.

Most analyses of employment change use aggregated occupational descriptions because collection and manipulation of more detailed occupational data are costly, and because the most detailed descriptions fall easily out of date. Many experts believe that analysts have been handicapped by the kinds of data available. For example, the most recent edition of the *Dictionary of Occupational Titles* (DOT), which describes 200,000 occupations, was published 6 years ago in 1977 (the previous edition was published in 1965). The DOT does not contain an entry for "robot technician, " and the most similar entry, "automated equipment engineer technician," refers to an individual who works with machinery producing items from paper or cardboard stock (as opposed to metal, plastic, or other materials with which robots or other forms of programmable automation might be used).

How can the effects of programmable automation on employment levels and distribution among occupations be gaged? Already, there are many estimates of the overall and occupational employment impacts of programmable automation appearing in the trade, popular, and business presses. Examples include the following:

> Automotive industry sources say the general formula is that 1.7 jobs are lost for every robot introduced.[3]

> "Automation will cause a 20 to 25 percent decline in the factory work force over the next decade, " says Thomas G. Gunn, managing director of Arthur D. Little's computer integrated manufacturing group. An internal study done by GE shows that it is now technologically possible for the company to replace half of its 37,000 assem-

[3]Joyce Price, "With Robots On the Way, GM Workers Worry," *The* (Baltimore) News *American,* Sept. 27, 1982.

bly workers with machines. Company officials are quick to point out that they have no plans to do that and where GE is automating existing plants—at Erie, for instance—it is retraining the displaced workers. Sometimes extensive automation also creates new jobs even as it destroys others. The new automated parts factory in Florence, Ky., for example, will allow Yamazaki to expand production at its manned machine-tool assembly plant nearby; 100 workers will be hired to fill the new jobs.[4]

Experts estimate that on the order of 45 million existing jobs—45 percent of all jobs, since there are about 100 million people at work—could be affected by factory and office automation. Much of the impact will occur before the year 2000. . . The United Auto Workers, one of few unions that tries to anticipate automation expects its auto industry membership to drop to 800,000 from 1 million between 1978 and 1990, even assuming a 1.8 percent annual increase in domestic auto sales . . . . Harvey L. Poppel, a senior vice-president with Booz, Allen& Hamilton, Inc., estimates that 38 million of more than 50 million existing white-collar jobs eventually may be affected by automation. Paul A. Strassmann, vice-president of strategic planning for Xerox Corp.'s Information Products Group, predicts that 20 million to 30 million of these jobs will be affected by 1990.[5]

Forecasting is, at its best, imprecise. However, the impact of robotics will definitely mean the elimination of some blue-collar jobs and the creation of jobs that didn't exist as recently as 10 years ago. It's estimated that there are currently 10,000 workers involved in robotics in some form or another throughout the world. That includes everyone from assembly line workers to designers, engineers, company presidents, clerical help, maintenance people and all of the support necessary for a young, developing industry.[6]

The above sources have derived their estimates through various means. The estimation procedures used appear to fall into two categories: "engineering" and "economic." Both categories derive labor requirements from other phenomena: equipment in the former category, and demand for finished products in the latter. These procedures are reviewed below to illustrate how limited current understanding and modeling of programmable automation employment impacts really are.

Engineering Estimates

Engineering estimate is the term used in this report to refer to an estimate based more or less exclusively on technical aspects of technological change. Although engineering analyses may be used to support economic analyses of employment change, they are frequently used on their own. Most of the employment (or, in particular, unemployment) estimates cited in popular discussions of programmable automation seem to be of this type.

Engineering estimates are made by describing the capabilities (for physical and mental work) of new automation technologies, projecting capability improvement over time, comparing the capabilities to tasks performed by humans, relating human tasks to different occupations, and deriving the number of jobs, by occupation, that could be assumed by new and future improved types of equipment. This is done by comparing guesses as to the percentages of work that could be transferred to programmable automation with counts of the numbers of people currently doing that work. For example, the employment impact of a welding robot might be estimated by identifying the types of welds the robot can perform, measuring the number of welds the robot can perform in a given period of time, and calculating the number of "jobs" that might be displaced by comparing the number of robots needed to achieve a given volume of welds with the number of human welders who could achieve the same volume of welds, given contemporary hiring patterns. Projected improvements in robot welding, or other changes in the basic assumptions can be accommodated by modifying the calculations.

Similar calculations are used to derive the employment requirements for producing the supply of robots necessary to achieve a given level of displacement —estimate the type of tasks required to produce robots, the number of tasks of each type required per robot, the allocation of robot-

[4]"The Factory of the Future," *Business Week,* Sept. 6, 1982.
[5]"Changing 45 Million Jobs," *Business Week,* Aug. 3, 1981.
[6]Joel Weber, "Can Robots Do a Better Job?" *D&B Reports,* January/February 1980.

production tasks between humans and equipment, and combine with the number of robots desired in a given period to forecast producer employment requirements.

Shortcomings of Engineering Estimates

The engineering approach is easily understood, adaptable to different assumptions, and useful as a first step in estimating the potential employment impacts of programmable automation. However, it has many limitations—in its application, if not its concept—which are largely functions of the narrowness of the technological and/or economic assumptions chosen. Shortcomings of engineering estimates may include some or all of the following:

- These estimates are easily confounded by errors in projecting future technological capabilities. Although providing a range of assumptions may improve the usefulness of the estimates, there remains a problem of inability to foresee all possible developments, especially in new technologies.
- Both the development and the analysis of automation technologies (conventional and also programmable) often rely heavily on point-by-point comparisons of electronic and mechanical capabilities with human capabilities, an orientation that lends itself to calculations of how and where automation equipment and systems may replace or substitute for human activities. See table 2. However, this orientation fails to capture the potential for programmable automation either to perform jobs in ways other than simulation of human behavior, or to perform jobs that are poorly done or not done at all by humans because of human limitations. This failure may lead to overestimation or underestimation of job displacement.
- Engineering estimates may be misleading because they tend to yield a "technically" ideal mix of humans and equipment, while the actual mix may reflect complex management and implementation considerations that are independent of the capabilities of specific equipment or systems. For example, managers may be motivated out of risk aversion to provide redundant capabilities in the form of "extra" workers (or overskilled workers) to provide manual performance backup or monitoring services, at least in the short term when programmable automation is relatively unfamiliar. Varying assumptions about the mix of humans and equipment would ease this problem.
- Engineering estimates are frequently based on current or recent labor force characteristics. This practice assumes that users will buy and use programmable automation to serve relatively constant production needs, and that workers will seek different jobs at constant rates. However, the job displacement and creation consequences of programmable automation will depend not only on how programmable automation affects the number and type of tasks per worker, but also on how sales volume and the mix of products—which determine the total number of tasks done at all—change. These quantities may vary in response to factors other than technological change, such as shifts in consumer tastes. In addition, the employment consequences of programmable automation will depend on the numbers and types of people willing and able to work at different types of jobs, which also may vary independently of technology.

Engineering analyses are useful for identifying the types of people (excluding, perhaps, managers) who may be affected by programmable automation. As currently used, they are often too simplistic to provide realistic estimates of industry or economywide employment change. The chief problem with available engineering estimates of national employment impacts seems to be a lack of consideration for variations in economic conditions, trade patterns, and labor supply, although these factors probably could be accommodated by engineering analyses. Nevertheless, the engineering approach provides a framework that can be used to evaluate the employment consequences of alternative strategies for implementing programmable automation, and a mechanism for evaluating specific variations in production processes.

Table 2.—Comparison of Robot v. Human Skills and Characteristics

Robot[a]	Human
A Act/on and manipulation	
1. Manipulation abilities	
a. One or more arms. Automatic hand change is possible.	a. Two arms—two legs—multipurpose hands.
b. Incremental usefulness per each additional arm can be designed to be relatively higher than in humans.	b. Two hands cannot operate independently.
c. Requires the same amount of feedback throughout operation.	c. Feedback requirements (type and quantity) change with practice—initially relatively higher than robot; visual feedback dominates other sources of feedback.
d. Movement time related to distance moved by speed, acceleration and deceleration, and will increase with higher accuracy requirements.	d. Movement time and accuracy governed by Fitts law. High precision movements may interfere with calculation processes.
. . .	
B. Brain and control	
1. Computational capability	
a. Fast, e.g., up to 10 Kbits/sec for a small minicomputer control.	a. Slow—5 bits/see.
b. Not affected by meaning and connotation of signals.	b. Affected by meaning and connotation of signals.
c. No valuation of quality of information unless provided by program.	c. Evaluates reliability of information.
d. Error detection depends on program.	d. Good error detection/correction at cost of redundancy.
e. Very good computational and algorithmic capability by computer.	e. Heuristic rather than algorithmic.
f. Negligible time lag.	f. Time lags increased, 1 to 3 sec.
g. Ability to accept information is very high, limited only by the channel rate.	g. Limited ability to accept information (10 to 20 bits/sec).
h. Good ability to select and execute responses.	h. Very limited response selection/execution (l/see); responses may be "grouped" with practice.
i. No compatibility limitation.	i. Subject to various compatibility effects (RR, SR, SS).
j. If programmable—not difficult to reprogram.	j. Difficult to reprogram.
k. Random program selection can be provided.	k. Various sequence/transfer effects.
1. Command repertoire limited by computer compiler or control scheme.	1. Command repertoire limited by experience and training.
2. Memory	
a. Memory capacity from 20 commands to 2,000 commands, and can be extended by secondary memory such as cassettes.	a. No indication of capacity imitation.
b. Memory partitioning can be used to improve efficiency.	b. Not applicable.
c. Can forget completely but only on command.	c. Directed forgetting very limited.
d. "Skills" must be specified in programs.	d. Memory contains basic skills accumulated by experience.
	e. Slow storage access/retrieval.
	f. Very limited working register = 5 items.
3. Intelligence	
a. No judgment ability of unanticipated events.	a. Can use judgment to deal with unpredicted problems.
b. Decisionmaking limited by computer program.	b. Can anticipate problems.
. . *	
E. Miscellaneous factors	
. . *	
3. Training	
a. Requires training by teaching and programing by an experienced human.	a. Requires human teacher
b. Training doesn't have to be individualized.	b. Usually individualized is best.
c. No need to retrain once the program taught is correct.	c. Retraining often needed due to forgetting.
d. Immediate transfer of skills ("zeroing") can be provided.	d. Zeroing usually not possible.
	e. Very costly.
	f. Not everyone can be taught.
4. Social and psychological needs	
None	a. Emotional sensitivity to task structure—simplified/enriched; whole/part.
	b. Social value effects.
5. Individual differences	
Only if designed to be different.	100 to 150 percent variation may be expected.

[a]Robot parameter values are cited from currently available Industrial robot literature.

SOURCE: Nof, Knight, and Salvendy, "Effective Utilization of Industrial Robots—A Job and Skills Analysis Approach," *AIIE TransactIons,* vol. 12, No. 3, September 19S0.

Economic Estimates

Economic estimates is the term that will be used in this technical memorandum to refer to projections based on macroeconomic models. Economic estimates are better than engineering estimates for projecting aggregate changes in employment patterns because they are inherently more comprehensive. On the other hand, economic estimates may not be practical or useful for gaging possible employment change at the company level because they tend to be highly aggregated.

Economic estimates are made by explicitly evaluating several factors, in addition to technology, that impinge on employment demands. For example, prices and production levels of goods and services are typically considered, taking into account, in turn, the forces that affect these factors, such as international trade and projected shifts in the relative strengths of different sectors of the economy. Economic estimates place substantial emphasis on descriptions of employers in terms of different sectors of the economy and different industries within sectors. They rely on engineering analyses for descriptions of alternative effects of technologies on industry requirements for such production inputs as labor (by occupation), equipment, and materials.

Economic estimates of employment change are made using mathematical models of production functions, which describe how different inputs to production are combined to yield a given level of output. Some models pertain to single industries, while other, more elaborate models also take into account the interactions among industries. The most detailed economic estimates come from large-scale models, in particular those based on so-called input-output (I-O) models, which encompass entire (regional, national, or global) economies. Technologies are defined in I-O models as the structure—number, type, and proportions—of inputs associated with the production of a unit of output of a given product.

The employment forecasts (total and by occupation) of the BLS draw on large-scale economic modeling. They are generated with an I-O model of the U.S. economy in combination with other models that forecast change in the labor force and in the level and pattern of economic activity. Also included are descriptions of staffing patterns (the mix by proportion of different types of workers) for each industry included, obtained from periodic surveys. Since the BLS estimates are widely used, and since the procedures are substantially similar to procedures used by others who forecast with large-scale economic models (indeed, other models often use the same data), a description of the outlines of BLS forecasting procedures can serve as a description of economic employment forecasting procedures in general (although individual models and procedures do differ in their details). *

Figure 1 shows the different computational elements that contribute to BLS forecasts. The first set of procedures is the projection of labor force characteristics. The second set of procedures is the projection of overall economic activity and resulting gross national product. These projections require estimation of the types and volumes of goods and services the economy can produce or supply in both private and public sectors, and those that will be demanded by the public and private sectors. The third set of procedures translates overall economic projections into projections of industry activity, allocating estimated consumer spending among product groups and allocating products to producing industries. Estimated gross private domestic investment is in turn allocated between changes in business inventories and investments in construction (residential and nonresidential) and producer-durable goods (e.g., machinery and tools). The fourth set of procedures translates projections of industry output into projections of industry employment. This is done by a combination of procedures for estimating labor productivity (defined as output per unit of labor input) and weekly hours of work for each industry.

The final set of procedures yields projections of employment by occupation and by industry. It combines descriptions of staffing patterns obtained by periodic surveys with estimates of the

*Note that BLS has recently contracted with Chase Econometrics Associates, Inc., to use the Chase macroeconomic model to develop projections of aggregate economic activity, using assumptions and variables chosen by BLS. This arrangement will supplement in-house BLS modeling and analysis.

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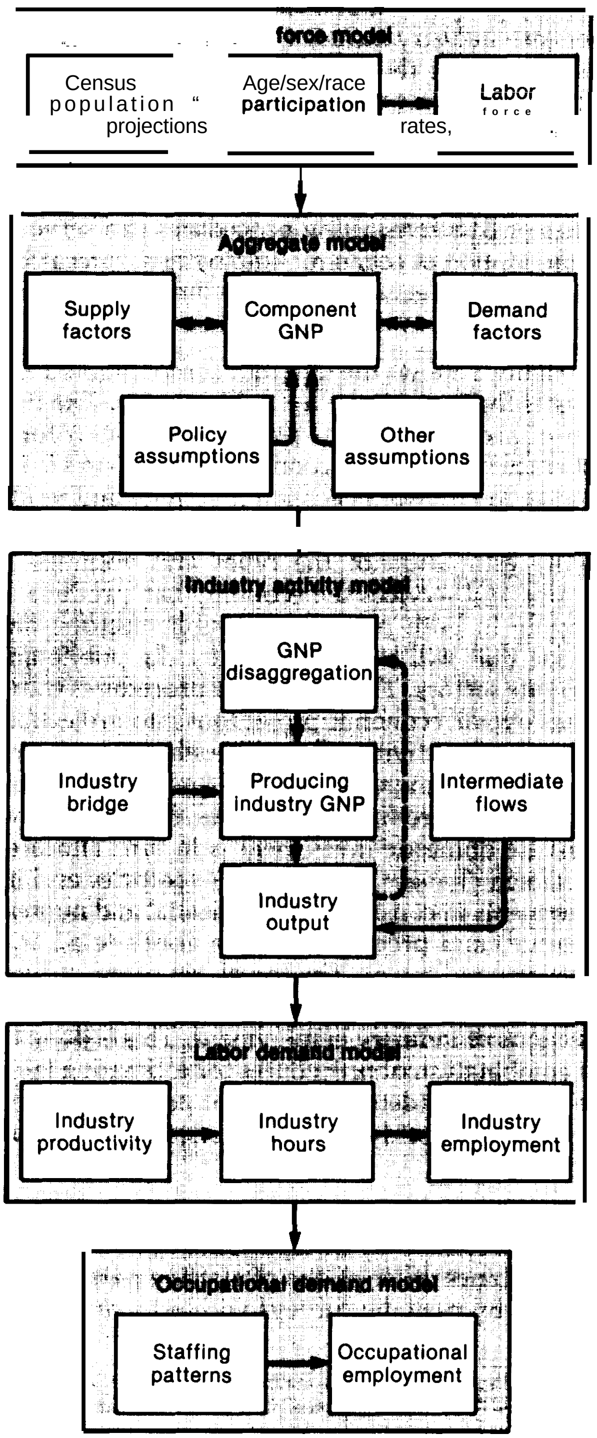
Figure 1.—Bureau of Labor Statistics Employment Projections System



SOURCE: U.S. Department of Labor, Bureau of Labor Statistics, "BLS Economic Growth Model System Used for Projections to 1990."

number of jobs per industry. All of these procedures are described in detail in the BLS publication, *BLSEconomic Growth Model System Used for Projections to 1990,* April 1982.

Shortcomings of Economic Estimates

As the description of the BLS procedures shows, large-scale economic models can take into account the growth and decline of different industries, the likelihood that individual industries adopting new technologies may maintain or increase output levels, and the responsiveness of industry employment levels to industry technology change. This framework prevents overattributing employment changes to single influences such as technology change, as it shows the consequences of combinations of influences. In their detail, however, the validity of the projections generated depends on the assumptions that underlie the formulation and operation of each aspect of the model and the integration of the different aspects. Moreover, the use of large-scale economic models carries the risk of oversimplifying complex processes and conveying an impression of greater analytical thoroughness than may actually exist.

Several questions have been raised about the assumptions used in large-scale economic forecasting models. The following list of some of the shortcomings of economic estimates reflects concerns raised by participants at the OTA Labor Markets and Industrial Relations Workshop, who debated whether economic models could adequately evaluate the impacts of programmable automation on employment. It also reflects concerns raised by others regarding economic modeling in general and modeling of technological change impacts in particular.

- *Labor Supply. The* growth of the labor force and change in labor force participation rates of specific groups depend in complex ways on demographic and economic factors. These relationships may not be captured in economic models which project labor supply and industrial output profiles separately. * Also, variations in the quality, rather than the quantity, of available labor maybe beyond

*BLS is currently working to improve its treatment of demographic and economic influences on the labor force.

the scope of contemporary large-scale economic models. Consequently, the output of large-scale economic models may best be viewed as projected demands rather than employment levels, per se.

- Technological Change. It is unclear how well large-scale models account for changes in equipment technologies. Although the common practice of projecting future capital stock by extrapolating from past use of plant and equipment and past descriptions of industries and products suggests that economic models may be unable to capture the impacts of nontraditional equipment, experts disagree as to whether measures of specific new technology attributes are necessary for deriving economic estimates of employment change. See papers by L. Jacobson/R. Levy and F. Duchin, appendix C. In addition, economic models typically are constructed using the assumption that technological change is adopted to reduce unit costs, although it may also be adopted for other reasons (e.g., to meet health or pollution standards) leading to cost increases.
- *Staffing* Patterns. Employment change due to reorganization of production associated with programmable automation may not be captured where occupational employment is projected using staffing patterns derived from prior practices. Similarly, changes in occupational content may not be accounted for. BLS, for example, has found that many of the largest errors in its past estimates of occupational employment "resulted primarily from misestimates of industry-occupational staffing patterns."[7] The development of adequate staffing patterns would appear to require engineering analyses that take into account possible variations in the implementation of programmable automation, alternative levels of integration of manufacturing activities, and alternative approaches to accommodating existing company work forces.

Like engineering estimates, economic estimates have several shortcomings. However, while engineering estimates tend to highlight job displacement impacts of new technology, economic estimates are better suited for evaluating whether persons displaced from particular industries may find job opportunities in other industries requiring their skills, and therefore whether job displacement is likely to be associated with unemployment. How well they do this depends on how well they capture the different components of the economy and their interactions. Similarly, while engineering estimates may establish new needs for individuals with certain skills, economic estimates may more readily provide perspective on economywide demand for such individuals and therefore whether demand for certain skills or occupations is likely to exceed or fall short of supply. These differences arise because economic analyses as a rule model the interactions among segments of the economy, while engineering analyses do not, even though they may apply to the nationwide use of a technology. However, valid inferences regarding future unemployment and labor shortages require that engineering analysis, economic and industry analysis, and labor supply analysis be considered together.

[7]Carey and Kasunic, op. cit.

BEYOND HARDWARE AND SOFTWARE: OTHER FACTORS TO BE CONSIDERED

In general, satisfactory projections of the magnitude and distribution of employment shifts associated with programmable automation should take into account a variety of factors that contribute to the direct and indirect effects of the new technology. Among these are changes in the organization of production, in the level of output among industries, and in the overall mix of employment opportunities in the economy. These changes will reflect the basic parameters described in the introduction (rate, nature, and diffusion pattern of technological change) and also the influence of institutional factors such as labor-management agreements and norms, which affect the rate and manner of application of new technologies. Labor-management relations are examined in appendix B.

Organization of Production

Change in the mix and volume of activities among users of programmable automation will depend on alteration of the organization of production (and concomitant changes in product lines) that may occur as a result of its use. As discussed in chapter 1, it is anticipated that the spread of programmable automation will involve both technologies embodied in automated equipment and systems and disembodied technologies in the form of organization and management changes. These changes may be most pronounced in small-volume or batch production settings:

> For a long time the *functional layout* in batch production, that is, all machines of the same kind are gathered in groups, has been as natural as the transfer line in mass production. Through the functional layout, machine utilization can be kept high, but at the expense of complex routing of parts through the shop and large buffers and inventories. . . . In the new manufacturing methods the main principle is to organize the factory according to *product-oriented* layouts. All machines needed to produce one product or one set of products are grouped together in a "subfactory," sometimes with its own administration. Each worker in product-oriented layouts attends several machines. In the functional layout we can with some simplification say that the materials wait for the machines while the machines in the product-oriented layout wait for the materials. The lead time (defined as the total time needed for material to be processed into a finished product) can thereby be reduced dramatically.[8]

Production may also be reorganized between facilities, as programmable automation facilitates regional and even international reorganization of production activities. For example, Ford Motor Co.'s Erika project (which resulted in the Escort and Lynx cars in the United States and similar cars in other markets) used "the largest collection of computer design hardware under one roof" to pool U.S. and European product design and analysis efforts, eliminating separate parallel efforts on different continents.[9] Although there has been much speculation among technology and industry analysts about potential employment effects of production reorganization, little reorganization appears to have taken place, in part because business management has either failed to understand or resisted such change, and in part because the integration aspects of programmable automation appear insufficiently developed.l"

Output Level

The employment consequences of programmable automation production and use depend not only on the mix of manufacturing activities, but also on production volume for both automation and end products made with it. Since programmable automation will be sought by both new users and customers previously using other types of equipment, production volume should be evaluated by taking into account possible reductions in volume of other, older technology equipment and systems. This offset problem is generally recognized in evaluating the impacts of microelectronics-based (and other) technologies found in both new products and new production processes.

> (I)t is clear that microelectronic technologies will create jobs in those industries manufacturing novel electronic products. The $4 billion now being lavished on electronic watches, calculators, games, and other microelectronic products has spawned a whole industry that did not even exist a decade ago. According to a projection by . . . Arthur D. Little, the manufacture of these items, together with computers and other electronic equipment, could create about 1 million new jobs between 1977 and 1987 in the United States and Western Europe combined. About 1.5 million people are now employed in the electronics industry in the United States. But these jobs will not represent net additions to the work force, for they will be offset to some extent by job losses in the manufacture of goods with which the new microelectronics-based products are competing.[11]

[8]"The Promotion of Robotics and CAD/CAM in Sweden," report from the Computers and Electronics Commission, Ministry of Industry (Sweden), 1981.

[9]*Automotive News*, Feb. 15, 1980.

[10]See for example: Bela Gold, "CAM Sets New Rules for Production," Harvard *Business Review*, November-December 1982.

[11]Colin Norman, "Microelectronics at Work: Productivity and Jobs in the World Economy," Worldwatch Paper 39, October 1980.

The net effects of programmable automation on user employment will depend on the effect it has on end-product prices and on foreign trade, product specialization, and other conditions in user markets in the United States and abroad. These factors, together with technology and general economic conditions, determine growth in domestic company sales volume.

Employment Opportunity Mix

Overall, employment effects of programmable automation will also depend on changes in employment opportunities throughout the economy. EconomyWide changes in employment activities depend in part on the pattern of diffusion of programmable automation and in part on the pattern of change in the mix of products available. Thus, although the apparent long-term decline in the manufacturing share of total U.S. employment (which began prior to widespread use of programmable automation) reflects the adoption of labor-saving technologies, the slow long-term growth in the absolute level of U.S. manufacturing employment illustrates the importance of sales volume and market growth (including the introduction of new products). It can be misleading to evaluate the employment impacts of new processes from the perspective of a constant mix of finished products because the number as well as the mix of goods and services provided to both producers and consumers is dynamic. Such evaluations are common, however, because the existing mix of products is known, while future product arrays are not.

LABOR SUPPLY

While employment demands may change because of the characteristics of programmable automation technologies and of industries producing and using them, change in employment (and unemployment) patterns also depends on the characteristics of the supply of labor: who is available to do the work offered by employers, how able people are to do different types of work, and whether there are too many or too few people with different abilities to do the work offered. The following is a brief overview of labor supply attributes and concerns.

Demography

The number of people willing and able to work, usually counted between the ages of 16 and 65, depends on several factors, including natural population growth, * immigration and emigration patterns, public health conditions, the age structure of the population (the proportions by age), and the willingness of people to work, given the levels of available wages and salaries and alternative sources of income. The overall size, growth rate, and age structure of the population are important measures of the availability of people in gross numbers to do work using particular technologies to support a given level of economic activity. Attitudes toward work and other social factors, which vary among geographic areas and ethnic groups, contribute to the actual numbers and types of people participating in the labor force.

Age structure and fertility patterns are particularly important influences on the makeup of the labor force. Fertility patterns, in combination with economic conditions and social norms, influence the labor force participation of women as well as the age structure of the population. The earlier and more frequently women give birth, for example, the younger the population is likely to be and the greater the (eventual) influx of new entrants to the labor force. Delays in and decreases in the incidence of marriage and childbearing over the past two decades have been causing the U.S. population to age by reducing the proportion of children. The age structure, in turn, influences: 1) the proportion of the population which is too young and/or too old to work and therefore dependent on the economic activity of the working-age population, 2) the overall rate of population growth, and 3) the numbers of new entrants to

● Natural population growth reflects mortality and in particular fertility (childbearing) rates, both of which may vary geographically, and among subgroups.

the labor force. Consequently, differences in age structure among countries influence national differences in employment patterns, preferences, and policies. The Japanese, for example, are reported to have shown early interest in programmable automation in part because "aging" of their population limited the supply of young workers.[12]

The composition of the American population has shifted toward older age groups more slowly than that of the Japanese population, but the supply of new entrants to the labor force is expected to begin a long-term decline in the 1980's. Federal projections of the U.S. population through the year 2050 show the number of teenagers to peak in 1980. The U.S. elderly population is expected to grow from the 1980 level of 25.7 million to 67.1 million by 2050, increasing from 11 to 21.7 percent of the population .13 Unless the propensity of the elderly to work increases dramatically, this population shift will reduce the overall exposure of the U.S. labor force to job displacement, and it may eventually increase demand for labor-saving technologies.

Qualitative Attributes

Other characteristics of the labor force important to understanding employment trends are qualitative. They include level, type, and quality of education or training; skills; and preferences regarding different types of work. Education and training are important determinants of skills and therefore of the types of work individuals can do. However, educational attainment is an imprecise measure of the qualities of workers, since skills can be obtained through means other than formal instruction. A discussion of education, training, and retraining can be found in chapter 3.

Occupational Structure

The characteristics of the labor force, together with the array of jobs available, contribute to the occupational structure of an economy-the distribution of workers among occupations. Labor force attributes, and occupational structure in particular, change over time with changes in demography and with changes in social norms, both of which reflect economic conditions. For example, the absolute and relative growth in service sector employment has been associated with the growth in female labor force participation.

Key attributes of the 1980's labor force in the United States include growing proportions of older workers, relatively large proportions of women and minorities, relatively large proportions of college-educated workers, and declining numbers of people willing to work in low-level occupations.[14] Tables 3 and 4 display basic characteristics of the U.S. labor force.

It is important to note that, as long as different groups don't radically change their propensities to seek employment, it is relatively easy to describe the physical characteristics of the labor force 10 to 12 years into the future since these people have already been born. However, describing future occupational preferences and distribution is less straightforward, since there are many paths—not all measurable—for moving into different jobs and occupations and many alternative paths into, out of, and through the labor force.

Adaptability of Labor

A key issue in evaluating the adaptability of the labor force to changing labor demands—and therefore the likelihood of unemployment as a consequence of technology change-is the willingness and ability of people to perform different types of jobs if the jobs they have held, or would prefer to hold, become unavailable. Because this flexibility depends in part on "objective" worker traits such as specialized skills, and in part on "subjective" traits, such as personal preferences for certain kinds of jobs, it is difficult to evaluate the true fit between labor supply and labor demand in the wake of circumstances such as technology change that alter employment requirements. A poor fit may be revealed in under-

[12] G. K. Hutchinson, "Flexible Manufacturing Systems in Japan" (Milwaukee, Wis.: University of Wisconsin Management Research Center, November 1977).

[13] Robert Pear, "Population Drop Predicted in U.S.," New *York Times, Nov.* 9, 1982.

[14] See, for example, Howard N. Fullerton, "How Accurate Were Projections of the 1980 Labor Force?" *Monthly Labor Review,* July 1982.

Table 3.–Noninstitutional Population and the Labor Force, 1929-82

(monthly data seasonally adjusted, except as noted)

Year of month	Noninstitutional Population	Armed Forces	Civilian labor force: Total	Employment: Total	Employment: Agricultural	Employment: Nonagricultural	Unemployment	Unemployment rate (percent of civilian labor force)	Civilian labor force participation rate[2]: Total	Males	Females
	Thousands of pesons 14 years 01 age and over							Percent			
1929		260	49180	47630	10450	37180	1 550	32			
1933		250	51590	38760	10090	28670	12830	249			
1939		370	55230	45750	9610	36140	9480	17.2			
1940	100380		55640	47520	9540	37980	8120	146	557	837	282
1941	101520	I M	55910	50350	9100	41250	5%0	9 9	56 0	843	287
1942	102610	3970	56410	53750	9250	44500	26-50	47	572	856	31 3
1943	103660	9020	55540	54470	9080	45390	1070	19	5s7	864	360
1944	104630	11410	5A 630	53960	8950	45010	670	1.2	586	870	365
1945	105530	1 I 440	53860	52820	8580	44240	MO	1.9	572	848	359
)946	106520	3450	57520	55250	8320	46930	2270	3.9	558	826	31 2
1947	107608	1590	60168	57812	8256	49557	2356	39	568	840	31 0
	Thous	Is of person	s 16 ye,	of age and Over							
1947	103418	1591	59350	57038	7890	49148	2311	39	583	864	318
1948	104527	1456	60621	58343	7629	50714	2276	38	588	866	327
1949	105611	1616	61286	57651	7658	49.993	3637	59	589	864	331
1950	106645	1649	62208	58918	7160	51758	3288	53	592	864	339
1951	107721	3098	62017	59961	6726	53235	2055	33	593	845	346
1952	108823	3593	62138	60 250	6500	53749	1 ea3	30	590	& 3	347
19533	110601	3547	63015	61.179	626o	54919	1834	29	589	& O	344
1954	111 671	3350	63643	60109	6205	53904	3532	55	588	855	346
1955	112732	3048	65023	62170	6450	55722	2852	44	593 '	853	357
1956	113811	2856	66552	63799	6283	57514	2750	41	600	855	369
1957	115065	2799	66.929	6A 071	5947	58123	2859	43	596	848	
1958	116363	2636	67639	63036	5586	57450	4 602	68	59 ~	842	: ;
1959	117881	2551	68369	6-4630	5565	59065	3740	55	593	837	371
1960 [1]	119759	2514	69628	65778	5458	60 318	3852	55	594	833	377
1961	121343	2572	70459	65746	5200	60546	4714	67	593	829	38 1
1962>	122981	2827	70614	667021	4944	61759	3.911	55	588	820	379
1963	125154	2137	71833	67762	4687	63076	4070	57	587	814	383
1964	127224	2138	73091	69305,	4523	M 782	3786	52	587	810	387
1965	129236	2722	74455	71088	4361	66726	3366	45	589	807	393
1966	131180	3122	75770	72895	3,979	68915	2875		592	804	403
1967	133319	3446	77347	74372	3844	70527	2975	: !	596	804	411
1968	135562	3534	78737	75920	3817	72103	2811	36	596	8 0 1	416
1969	137841	3 506	80734	77902	36Q6	74 2%	2832	35	601	798	427
1970	140272	3188	82771	78678	3463	75215	4093	49	J34	797,	433
1971	143033	2816	84387	79367	3394	75972	5016	59	Q 2	79 I	434
1972[3]	146574	2449	87034	82153	3484	78669	4882		604	789	439
1973[3]	149423	2326	89.429	064	3470	81.594	4365	:	438	788	447
1974	152349	2229	91949	794	3515	83279	5156	56	1 3	7 8 7	457
1975	153333	2180	93775	85846	3408	82438	7929	85	1 2	779 '	463
1916	158294	2144	96158	88752	3331	85421	7406	77	616	775	473
1977	161166	2133	99009	92017	3283	88734	6991		623	777	484
1978[3]	164027	2117	102251	048	3387	92 661	6202	1	632	719	500
1979	166951	2088	M 962	98824	3347	95477	6137	58	637	778,	5439
1980	169848	2102	1069401	9303	3364	95938	7631	1	638	774	1 5
1981	172272	2142	108670	CKI 397	3368	'37 030	8273		639	7 7 0	521
1982	I74 45)	2179	110204	9526	3401	96125	10.678	!	640	166,	526
1980											
dn	168625	2081	106546	99872	3313	96559	6674	63	640	777	516
Feb	168846	2086	106637	99963	3387	96516	6674	63	639	778	1 5
Mar	169073	2090	106394	99677	4 1 2	96265	6717	63	637	775	513
'Apr,	169289	2092	106552	99204	3318	95886	7348	69	637	774	514
May	169494	2088	106892	98922	3385	95537	7970	75	639	716	515
June	169735	2092	106832	98769	3309	95460	8063	75	637	775	514
July	170 03C ~	2099	107.169	98816	3331	95485	8353	78	638	775	515
Aug	170217	2114	107.116	98829	3247	95582	8287	77	637	773	515
Sept	170419	2121	107.148	S$ 104	3448	95656	8044	75	637	773	514
Oct	170624	2121	107.438	99327	3362	95965	8111	75	638	773	516
Ncv,	170814	2119	107.596	99567	3387	96, 180	8029	75	638	773	516
Dec	171 Oc 7	2124	107.446	99650	3486	96,164,	7796	73	636	770	516
198:											
Jan	171229	2125	108.012	S9 964	3420	96 544	8 048	75 i	639	773	51 8
Feb	171400 '	2121	108.175	lrll 143	3340	96803	8032	74	639	772	520
Mar	171581	2128	108.471	ICWI 504	3356	97148	7967	731	640	773	521
Ap!	171770	2129	108.866	10 I 006	3519	97487	7860	72	642	774	523
May	171956	2127	109.101	100968	3371	97597	8133	7 5	642 '	774	524
June	172172	2,131	108.440	100393	3360	97033	8047	7 4	638	767	521
)Uly	172385	2139	108.602	100748,	3320,	97428	7854	72	6381	768	521
Aug	172559	2160	108.762	100 7C4	3396	97313	8053	74	638	769	521
Sept	172758	2165	108.375	100104	3358	96746	8271		635	767	517
Oct	172966	2158	109.028	100355	3374	96981	8673	; :	638	767	522
NOV	173155	2158	109.254	100229	3389	96840	9025	83	639	768	523
OH	173330	2164	109.066	99677	3219	6458	9389	86	637	767	520
19732											
Ia.	173495	2159	109.034	99688	3379	96309	9346 ~	86	636	765	521
Feb	173657	2168	109.364	99695	3367	96328	9669	88	638	766	523
Mar	173843	2175 /	109.478	99597	3367	6230	9881	90	638	765	523
AP{	174020	2176	109.740	99484	3356	96128	10256	93	639	766	524
May	174201	2175	110.378	99994	3446	96548	10384	94	642	770	527
June	174364	2173	110.147	99681	3371	96310	10466	95	6-40	765	527
July	174544	2180	110.416	99588	3445	96143	10828 ~	98 ~	641	765	529
Aug	174707	2196	110.614	99683	342'3	96254	10931	9.9	64 1	766	529
Sepf	174889	2198	110.858	99543	3363	96180	11315	10.2	64 2	768,	528
Oct	175069	2188	110.752	99176	3.413	95763	Ii 576	105	M 1	761	527
Nov	175238	2180	111.042	99136	3466	95670	11906	107	642	768	52.8
Oec	175380 ~	2182	111.129	99093	3 4)1	95682	12036	108	642	766	530

[1]Not seasonally adjusted
[2]Civilian labor force as percent of civilian non 3tltUtll al population
[3]Not strictly comparable with earlier data due to populati adjustments as follows" Beginning 1953, introduction of 1950 census data added about 600,000 to population and about 50,000 to labor force, total employment, and agricultural employment Beginning 1960, inclusion of Alaska and Hawaii added about 500,000 to population, about 300,000 to labor force. and about 240,000 to nonagricultural employment Beginning 1962, introduction of 1960 census data reduced population by about 50,000 and labor force and employment by about 200,000 Beginning 1972, Introduction of 1970 census data added about 800,000 to civilian noninstitutional population and about 333,000 to labor force and employment A subsequent adjustment based on 1970 census m March 1973 added 60,000 to labor force and 10 employment Beginning 1978, changes m sampling and estimation procedures introduced mto the household survey added about 250,000 fo labor force and to employment Unemployment levels and rates were not significantly affected

SOURCE Department of Labor Bureau of Labor Statistics

Table 4.–Wage and Salary Workers in Nonagricultural Establishments, 1929-82
(thousands of persons; monthly data seasonally adjusted)

Year or month	Total wage and salary workers	Manufacturing: Total	Manufacturing: Durable goods	Manufacturing: Nondurable goods	Mmrsg	Construction	Transportation and public utilities	Wholesale and retail trade	Finance, insurance, and real estate	Services	Government: Federal	Government: State and local
1929	31,324	10,702			1,087	1,512	3,916	6,123	1,494	3,425	533	2,532
1933	23,699	7,397	....		744	824	2,672	4,755	1,280	2,861	565	2,601
1939.	30,603	10,278	4,715	5,564	854	1,165	2,936	6,426	1,447	3,502	905	3,090
1940	32,361	10,985	5,363	5,622	W;	1,311	3,038	6,750	1,485	3,665	996	3,206
1941	36,539	13,192	6,968	6,225		1,814	3,274	7,210	1,525	3,905	1,340	3,320
1942	40,106	15,280	8,823	6,458	992	2,198	3,460	7,118	1,509	4,066	2,213	3,270
1943	42,434	17,602	11,084	6,518	925	1,587	3,647	6,982	1,481	4,130	2,905	3,175
1944	41,864	17,328	10,856	6,472	892	1,108	3,829	7,058	1,461	4,145	2,928	3,116
1945	40.374	15,524	9,074	6,450	836	1,147	3,906	7,314	1,481	4,222	2,808	3,137
1946	41,652	14,703	7,742	6,962	862	1,683	4,061	8,376	1,675	4,697	2,254	3,341
1947	43,857	15,545	8,385	7,159	955	2,009	4,166	8,955	1,728	5,025	1,892	3,582
1948	44,866	15,582	8,326	7,256	994	2,198	4,189	9,272	1,800	5,181	1,863	3,787
1949	43,754	14.441	7,489	6,953	930	2,194	4,001	9,264	1,828	5,240	1,908	3,948
1950	45,197	15,241	8,094	7,147	901	2,364	4,034	9,386	1,888	5,357	1,928	4,098
1951	47,819	16,393	9,089	7,304	929	2,637	4,226	9,742	1,956	5,547	2,302	4,087
1952	48,793	16,632	9,349	7,284	898	2,668	4,248	10,004	2,035	5,699	2,420	4,188
1953	50,202	17,549	10,110	7,438	; ; :	2,659	4,290	10,247	2,111	5,835	2,305	4,340
1954	48,990	16,314	9,129	7,185		2,646	4,084	10,235	2,200	5,969	2,188	4,563
1955.	50,641	16,882	9,541	7,341	792	2,839	4,141	10,535	2,298	6,240	2,187	4,727
1956	52,369	17,243	9,833	7,411	822	3,039	4,244	10,858	2,389	6,497	2,209	5,069
1957	52,853	17,174	9,855	7,321	;3;	2,962	4,241	10,886	2,438	6,708	2,217	5,399
1958	51,324	15,945	8,829	7,116		2,817	3,976	10,750	2,481	6,765	2,191	5,648
1959	53,268	16,675	9,373	7,303	732	3,004	4,011	11,127	2,549	7.087	2,233	5,850
1960	54,189	16,796	9,459	7,337	712	2,926	4,004	11,391	2,629	7,378	2,270	6,083
1961	53,999	16,326	9,070	7,256	672	2,859	3,903	11,337	2,688	7,620	2,279	6,315
1962	55,549	16,853	9,480	7,373	650	2,948	3,906	11,566	2,754	7,982	2,340	6,550
1963	56,653	16,995	9,616	7,380	635	3,010	3,903	11,778	2,830	8,277	2,358	6,868
1964	58,283	17,274	9,816	7,458	634	3,097	3,951	12,160	2,911	8,660	2,348	7,248
1965	60,765	18,062	10,405	7,656	:3;	3,232	4,036	12,716	2,977	9,036	2,378	7,696
1966	63,901	19,214	11,282	7,930		3,317	4,158	13,245	3,058	9,498	2,564	8,220
1967	65,803	19,447	11,439	8,007	613	3,248	4,268	13,606	3,185	10,045	2,719	8,672
1968	67,897	19,781	11,626	8,155	606	3,350	4,318	14,099	3,337	10,567	2,737	9,102
1969	70,384	20,167	11,895	8,272	619	3,575	4,442	14,705	3,512	11,169	2,758	9,437
1970	70,880	19,367	11,208	8,158	623	3,588	4,515	15,040	3,645	11,548	2,731	9,823
1971	71,214	18,623	10,636	7,987	609	3,704	4,476	15,352	3,772	11,797	2,696	10,185
1972	73,675	19,151	11,049	8,102	628	3,889	4,541	15,949	3,908	12,276	2,684	10,649
1973	76,790	20,154	11,891	8,262	642	4,097	4,656	16,607	4,046	12,857	2,663	11,068
1974	78,265	20,077	11,925	8,152	697	4,020	4,725	16,987	4,148	13,441	2,724	11,446
1975	76,945	18,323	10,688	7,635	752	3,525	4,542	17,060	4,165	13,892	2,748	11,937
1976	79,382	18,997	11,077	7,920	779	3,576	4,582	17,755	4,271	14,551	2,733	12,138
1977	82,471	19,682	11,597	8,086	813	3,851	4,713	18,516	4,467	15,303	2,727	12,399
1978	86,697	20,505	12,274	8,231	851	4,229	4,923	19,542	4,724	16,252	2,753	12,919
1979	89,823	21,040	12,760	8,280	958	4,463	5,136	20,192	4,975	17,112	2,773	13,174
1980	90,406	20,285	12,187	8,098	1,027	4,346	5,146	20,310	5,160	17,890	2,866	13,375
1981	91,105	20,173	12,1 17	8,056	1,132	4,176	5,157	20,551	5,301	18,592	2,772	13,253
1982 p	89,619	18.849	11,114	7.735	1,122	3,912	5.057	20,547	5,350	19,000	2,733	13,051
1981												
Jan	90,909	20,171	12,120	8,051	1,102	4,315	5,139	20,380	5,252	18,352	2,798	13,400
Feb	90,913	20,148	12,097	8,051	1,113	4,240	5,145	20,422	5,264	18,382	2,789	13,410
Mar	91,014	20,197	12,143	8,054	1,124	4,267	5,153	20,438	5,270	18,414	2,780	13,371
Apr	91,099	20,275	12,201	8,074	978	4,281	5,163	20,508	5,286	18,480	2,774	13,354
May	91,131	20,332	12,237	8,095	985	4,223	5,158	20,543	5,295	18,517	2,776	13,302
June	91,286	20,334	12,246	8,088	1,137	4,185	5,162	20,590	5,302	18,556	2,777	13,243
July	91,396	20,379	12,266	8,113	1,164	4,175	5,168	20,620	5,311	18,615	2,775	13,189
Aug	91,322	20,311	12,228	8,083	1,180	4,146	5,168	20,650	5,319	18,654	2,769	13,125
Sept	91.363	20,267	12,184	8,083	1,192	4,124	5,181	20,660	5,328	18,707	2,764	13,140
Oct	91,224	20,097	12,059	8,038	1,195	4,101	5,162	20,654	5,325	18,773	2,757	13,160
Nov	90,996	19,903	11,901	8,002	1,202	4,071	5,150	20,623	5,324	18,815	2,749	13,159
Dec	90,642	19,676	11,724	7,952	1,206	4,026	5,128	20,524	5,331	18,834	2,756	13,161
1982												
Jan.	90,460	19,517	11,622	7,895	1,201	3,966	5,125	20,630	5,326	18,831	2,741	13,123
Feb.	90,459	19,454	11,575	7,879	1,203	3,974	5,115	20,670	5,326	18,867	2,737	13,113
Mar	90,304	19,319	11,490	7,829	1,197	3,934	5,100	20,655	5,336	18,904	2,736	13,123
Apr	90,083	19,169	11,375	7,794	1,182	3,938	5,094	20,584	5,335	18,929	2,730	13,122
May	90,166	19,115	11,332	7,783	1,152	3,988	5,101	20,652	5,342	18,963	2,728	13,125
June	89.839	18,930	11,203	7.727	1,124	3,940	5,078	20,595	5,352	18,988	2,739	13,093
July	89,535	18,813	11,133	7,680	1,100	3,927	5,044	20,615	5,359	19,042	2,737	12,898
Aug	89,312	18,672	10,993	7,679	1,086	3,899	5,025	20,550	5,360	19,048	2,739	12,933
Sept	89,267	18,572	10,900	7,672	1,075	3,883	5,031	20,492	5,367	19,084	2,734	13,029
Oct	88,860	18,325	10,666	7,659	1,058	3,856	5,007	20,441	5,357	19,074	2,723	13,019
Nov p	88,684	18,183	10,555	7,628	1,051	3,848	4,994	20,390	5,362	19,125	2,726	13,005
Dec p	88,518	18,134	10,533	7,601	1,036	3,818	4,979	20,297	5,376	19,143	2,728	13.007

Source Department of Labor, Bureau of Labor Statistics employment* and unemployment, and in labor shortages.

Labor shortages exist where a sufficient number of particular types of people are unavailable for work at prevailing wages. Concern has been expressed by people in industry and in government about the economic effects of shortages in highly skilled craft and technical occupations, from machinists to certain types of engineers.** Alleged shortages have been cited as a motivation for investments in automation, and also in retraining. While retraining can ease shortages by increasing the supply of skilled workers, raising wages is another method of stimulating supply, although employers are often unwilling or unable to do this. Note that, for skills that take years to develop, instituting training programs (or raising wages) will not eliminate a shortage immediately.

A satisfactory analysis of labor supply issues associated with programmable automation should address such issues as contrasts in the composition of the U.S. labor force with that of other countries producing and using programmable automation, and the extent to which the production and use of programmable automation are influenced by labor shortages. Such issues are fundamental to the identification of components of the U.S. labor force that may be particularly helped or harmed by the spread of programmable automation, and the determination as to whether anticipated changes in the U.S. labor force are likely to cushion or exacerbate impacts that might arise from programmable automation.

● For example, according to BLS many college graduates during the 1970's took jobs not requiring college degrees.

● *The extent of current and possible future labor shortages that may affect the development or diffusion of programmable automation is unclear. Among the reasons that shortages are hard to measure are the following: 1) Federal programs do not collect occupational shortage statistics (due to cost and data reliability problems), 2) available data do not accurately capture employee mobility within and between occupations, 3) occupational classifications among firms and Federal statistical programs are inconsistent, and 4) employer and union surveys tend to be statistically unreliable. A recent analysis by BLS found after evaluating data from several sources that a machinist shortage could be neither established nor disproved.[15]

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

WORKING ENVIRONMENT

Introduction

Programmable automation may change not only the numbers and types of people working in manufacturing, but also the circumstances of work—what may be called the working environment. The ways in which programmable automation is applied will determine how it affects the working environment. This discussion of the potential implications of programmable automation for the working environment will address some of the issues concerning worker safety and health, human factors, job content, and structure of work.

Expressions of concern about the effects of technology on the conditions of work have increased in the United States over the past two decades. For a long time it was assumed by management that the benefits of more efficient production achieved through the introduction of new technologies far outweighed any negative effects on the work force. In other words, the assumption was that people could always adapt in some way to the requirements imposed by the technology.[16]

As in other countries, concerns about workplace conditions contributed to the growth of the labor movement in the United States. Since the mid-1960's, changing social and economic environments, characterized by an emerging awareness of individual rights and well-being, increased worker dissatisfaction, and declining productivity, have increased the importance of the working environment to both management and government, as well as labor. Workplace issues in manufacturing are currently being addressed in a number of ways, such as: 1) emphasis on human factors in the design of manufacturing equipment; 2) innovations in the structure of work; 3) increased cooperation between management and labor *in* solving workplace problems; and 4) a variety of

[16]Joel A. Fadem, "Automation and Work Design in the United States," in *International Comparative Study on Automation and Work Design,* International Labour Office, Geneva, January 1982, p. 25.

98-951 0 - 83 - 5

experiments in worker participation (such as quality control circles and quality of working life programs) intended to give workers greater input into decisions directly affecting their jobs. See table 5. These developments have met with varying degrees of success and commitment from management and labor. Nevertheless, they are part of the backdrop to the spread of programmable automa-

Table 5.—Labor-Management Committees on Industrial Relations Issues, Safety, and Productivity by Industry (agreements covering 1,000 workers or more, Jan. 1, 1980)

			Labor-management committees on—					
	All agreements		Industrial relations issues[a]		Safety[b]		Productivity[c]	
Industry	Agreements	Workers	Agreements	Workers	Agreements	Workers	Agreements	Workers
All industries.	1.550	659,800	`60	245,400	572	2,867,850	81	1,091,350
Manufacturing.	750	io2i150	39	1* 150		1,835,550	58	845,300
Food, kindred products	79	234,200	6	25,500	35	140,400	5	69,700
Tobacco manufacturing.	8	21,800	—	—	—	—	—	—
Textile mill products	11	28,850	—	—		1,200	—	—
Apparel	31	207,900	—	—		1,000	—	—
Lumber, wood products.	11	17,100	4	4,850	7	9,950	1	1,000
Furniture, fixtures.	17	23,100	1	1,000	8	7,400	1	1,000
Paper, allied products	42	65,000	1	1,100	18	27,650	1	1,200
Printing and publishing	15	31,600	1	1,000	3	10,800	2	9,100
Chemicals	36	61,700	1	1,200	21	30,850	1	2,000
Petroleum refining	15	25,500	—	—	10	18,900	—	—
Rubber and plastics ., ...	14	68,850	4	29,250	14	68,850	2	16,450
Leather products		23,100	—	—	2	3,200	—	—
Stone, clay, and glass	G	93,600	1	1,000	26	66,550	—	—
Primary metals	88	460,600	7	40,150	76	429,700	33	316,850
Fabricated metals.	41	97,000	2	3,200	25	66,150	3	5,050
Nonelectrical machinery	81	242,150	4	10,350	48	141,800	2	2,100
Electrical machinery.	83	323,750	3	8,200	42	130,300	—	—
Transportation equipment . . .	112	957,100	3	20,000	68	656,150	7	420,850
Instruments	11	27,650	1	1,350	4	16,700	—	—
Miscellaneous manufacturing	9	14,600	—	—	6	8,000	—	
Nonmanufacturing	800	456&650	21	97,250	159	1,032,300	23	246,050
Mining, crude petroleum, and naturai gas	16	169,050	2	6,000	13	161,200	3	10,100
Transportation	62	469,550	1	9,000	22	289,400	12	208,350
Communications.	80	620,000	4	45,000	37	316,050	1	1,550
Utilities, electric and gas . . .	81	210,700	2	4,300	35	108,050	2	4,900
Wholesaie trade	12	23,900	2	3,950	1	1,050	—	—
Retail trade	123	405,200	2	2,200	10	19,050	—	—
Hotels and restaurants	31	148,300	—	—		10,000	—	—
Services	66	323,450	5	22,100		8,800	2	3,650
Construction	327	1,195,000	3	4,700	34	118,700	3	17,500
Miscellaneous nonmanufacturing.	2	3.500	—	—	—		—	—

[a] A labor-management committee on industrial relations issues is a joint committee which studies issues, for example, subcontracting, seniority, and wa9e incentives, away from the deadlines of bargaining and makes recommendations to the negotiators. It also may be referred to as "prebargaining" or "continuous bargaining" committee. It should not be confused with labor-management committees which meet periodically to discuss and resolve grievances and in-plant problems.

[b] A labor-management safety committee is a joint committee which meets periodically to discuss safety problems, to work out solutions, and to implement safety programs in the plant.

[c] A labor-management committee on productivity is a joint committee which meets periodically to discuss in-plant production problems and to work out methods of improving the quantity and quality of production.

[d] Excludes railroads and airlines.

NOTE: Nonadditive.

SOURCE: U.S. Department of Labor, "Characteristics of Major Collective Bargaining Agreements, January 1980."

tion, and will influence how these technologies are implemented and how they affect the overall conditions of work.

Occupational Safety and Health

Occupational safety and health issues may be clearer than others associated with programmable automation. For example, the application of robots to painting and welding tasks is widely acknowledged as a measure that reduces worker exposure to occupational hazards by removing workers from the hazards. However, the use of robots and other forms of programmable automation may give rise to workplace hazards that are new and perhaps unanticipated.

The hazards associated with programmable automation are likely to be similar to those associated with industrial machinery, video display terminals (VDTs), and other types of equipment. With the introduction of programmable automation, there may be a shift of occupational safety and health concerns in manufacturing away from those directly involving machinery toward VDT-related issues. VDTs will become more numerous in manufacturing, and one possible outcome of the spread of programmable automation is an increase in the percentage of manufacturing workers using VDTs and a decrease in the percentage operating machinery. The eyestrain, stress, and back, neck, and shoulder problems recently documented by the National Institute for Occupational Safety and Health among workers who use VDTs for extended periods of time may become a problem for those using computer-aided design and manufacturing (CAD/CAM) systems.[17]

Unlike many older manufacturing technologies, programmable automation technologies are being developed in an era of greater awareness of occupational safety and health issues. Part of that context includes a body of Occupational Safety and Health Administration (OSHA) standards as well as a sophisticated set of nongovernmental technical standards. The applicability of current OSHA standards to the use of programmable automation will depend on the type of industry or nature of the operation involved. It is unclear whether or not programmable automation may give rise to a need for further OSHA standards.

Human Factors

Programmable automation may change the way job performance is evaluated in manufacturing. The computer and communications capabilities of programmable automation permit the recording and monitoring in remote locations of many aspects of equipment and system utilization, such as the number of operations performed per minute or per hour. Such monitoring would provide management with more information than individual piece counts conducted at the end of a day or week and other traditional measures of performance. Although sophisticated monitoring functions are not a necessary feature of programmable automation products, their possible use may reduce worker discretion in performing tasks and raise levels of stress among workers. Such results have been observed where office automation has been implemented with sophisticated monitoring features, such as tabulation of keystroke-per-minute rates.[18] On the other hand, if programmable automation requires fewer workers per machine, it may reduce the amount of direct personal supervision required.

Many of the effects, both physical and psychological, of programmable automation on people in the workplace will depend on the care and thought that go into the basic design of automated equipment and systems, and on whether the designers are concerned about human factors issues. Consideration of human factors involves first analyzing the roles people will play in a working environment using programmable automation, and then "examining such human factors engineering issues as design, procedurization, and protection."[19] Design engineers who do not work on the shop floor or in other manufacturing settings may not be sufficiently sensitive to the physiological

"'"Health Hazards for Office Workers: An Overview of Problems and Solutions in Occupational Health in the Office," *Working Women Educational Fund,* 1981, p. 22.

'Judith Gregory, Testimony for 9 to 5, National Association of Working Women, Hearings, House Subcommittee on Education and Labor of the Committee on Education and Labor, June 23, 1982, p. 10.

[19]H. McIlvaine Parsons and Greg P. Kearsley, "Human Factors and Robotics: Current Status and Future Prospects," Human Resources Research Organization, Alexandria, Va., prepared for U.S. Army Human Engineering Laboratory, October 1981, p. 13.

and psychological needs of the user. Whether or not the user is involved in the design process may determine to what extent the human needs of manufacturing personnel will be translated into equipment and systems designs.[20]

Although worker involvement in the design process would seem logical on the surface, it may also present a dilemma for manufacturing employees. While on the one hand their participation could improve the consideration of human factors, it could also facilitate the design of equipment that may eliminate jobs. This dilemma may inhibit the full participation of many workers in such activities as quality control circles and quality of working life programs.

Job Content

Programmable automation may affect job content in a number of ways and its impact on skill requirements is likely to be highly variable. By design, automated equipment and systems may alter the skills required for certain aspects of the production process, but the implications for specific jobs (e.g., in terms of the number and variety of tasks comprised) depend on how programmable automation is implemented. The impacts of programmable automation on skill levels are uncertain. While some jobs clearly will require a higher level of skill, others may require a lesser level, largely because much of the process-control decisionmaking may be incorporated into computer-controlled equipment and systems. It is unclear at this time whether the effects on skill levels are inherent in the programmable automation technology, or the extent to which innovative use provides a choice. Whether programmable automation will provide jobs that are more stimulating and satisfying overall than those in traditional manufacturing environments is uncertain. However, it is unlikely that all programmable automation jobs will provide more challenge, variety, and responsibility-nor does everyone require it.[21] There will probably always be monotonous jobs, and many workers accept this in return for such other benefits as fair wages and job security .22

Depending on how tasks are organized, programmable automation may allow an increase in the variety of tasks a worker performs.

> Therais also a close relation between the manufacturing technology chosen and the organization of work. However, technology is not the single determinant, so there is no specific organization corresponding to the use of a CAD/CAM system. Organizational philosophy has a predominant role, for example if one believes in complementary specialization of skills or in overlapping skills. The CAD/CAM may be a loyal servant to any work organization, provided that those who design and adapt the system know what they want.[23]

A restructuring of work in which both technical and human considerations are given equal treatment could offset the negative effects of changing skill requirements that may arise where old patterns of work organization persist.

Programmable automation may lead to changing roles and responsibilities at all levels, affecting both the nature of jobs and the distribution of power. The difficulties of reorganizing companies are well recognized. For example, change in the hierarchical structure (and thus control) brought about by the introduction of new technology may meet with resistance from those who might lose some authority .24 Consultants and trade and professional associations concerned with programmable automation have devoted much attention to the management challenges of successful use of programmable automation over the past few years. Clearly, management planning, practices, and policies will be key factors in how the introduction, implementation, and operation of programmable automation affects the overall working environment.

[20] Fadem, op. cit., p. 51.

[21] Eric Trist, 'The Evolution of Socio-Technical Systems: A Conceptual Framework and an Action Research Program, " Occasional Paper No. 2, Ontario Quality of Working Life Center, June 1981, p. 32.

[22] Sar A. Levitan and Clifford M. Johnson, *Second Thoughts on Work* (Kalamazoo, Mich.: W. E, Upjohn Institute for Employment Research, 1982), p. 212.

[23] "The Promotion of Robotics and CAD/CAM in Sweden," report from the Computers and Electronics Commission, Ministry of Industry (Sweden), 1981.

[24] Robert Schrank, Ten *Thousand Working Days* (Cambridge, Mass.: The MIT Press, 1978), p. 221.