Chapter 2

# Introduction

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## Background

A new wave of automation is spreading through manufacturing industries, and like its predecessors, it is receiving a mixed welcome. Computerized manufacturing automation–the application of electronic computer and communication tools to manufacturing-is viewed both as contributing to the problems faced by the U.S. economy and as part of the solution to those problems. * Those who view it optimistically emphasize its potential to improve productivity, work environment, product quality, and ultimately competitiveness. Those taking the opposite view argue that it will cause massive unemployment, make many jobs less rewarding, and provoke a retraining crisis. The rhetoric used by both sides makes it difficult to appraise the technologies and, more importantly, to determine what policies may be appropriate.

The economic and social effects of computers and automation in manufacturing have aroused concern since the late 1950's. During the late 1950's and early 1960's, people grew more aware of the potential uses of computer technology, while adoption of so-called hard or dedicated automation began to accelerate. Studies conducted during that period, including the report of a Federal study commission, drew conclusions about potential job loss, changing work conditions, and instructional needs that remain valid today.1 Because of technological developments and falling costs for computing during the late 1960's and the 1970's, the prospects for significant social and economic change resulting from wide use of computer technologies are more immediate today than before.

The current wave of automation is unlike its predecessors in several ways: Programmable automation (PA) can collect and process information as well as do physical work, allowing equipment for design, production, and management to be linked together. It can improve product quality by raising consistency and control in production. And it can be used in producing a range of products because of its reprogrammability. This trait, in particular, lies behind claims for PA "flexibility". These features make PA economical in production of much smaller quantities than hard automation, which is largely restricted to large quantity or mass production. They make PA applicable across a wide range of industries, whereas the applicability of conventional hard automation is much more limited. PA will have a major influence on skill requirements, product design and variety, production costs, job content, and the organization and management of manufacturing. Its features are fundamental to the potential changes in employment, work environment, and education and training needs that are a focus of this report.

The technical features of programmable automation and their economic and social ramifications will continue to make PA a source of controversy over the next decade. In particular, the economic aspects are central to the argument proponents make for rapid development and diffusion of programmable automation. Proponents claim that, in the current climate of international competition, manufacturing firms must either automate or move production overseas if they are to continue in business.* The basic argument states that PA will make domestic manufacturing more effi-

*The *subject* of this report is described as "manufacturing' rather than "factory' automation in order to emphasize that these tools can be applied not only to the fabrication of products but also to the critical functions of product design and manufacturing management. Related office automation technologies is being evaluated in a forthcoming OTA study, "Information and Communication Technologies and the Office. "

'Report of the National Commission on Technology, Automation, and Economic Progress, 1966.

Barring, that is, significant changes in import restraints or the value of the dollar.

cient and competitive, and it will thereby contribute to economic growth and greater employment.

The focus on economic growth reflects concern over the slow growth in productivity and economic output experienced during the 1970's and early 1980's. During that time, U.S. industries lost shares in domestic and foreign markets to foreign competitors, principally the Japanese. While the causes and significance of these phenomena are debated even among experts, popular consensus deems a key cause to be different production costs—in particular, different labor costs—among countries and industries. Lower costs abroad for labor have been a major reason, but not the only one,* for increases in overseas production by U.S. manufacturers as well as for increased imports of manufacturing goods. Against this background, the labor-savings aspects of PA technologies have taken on special significance.

Unfortunately, the popular focus on the labor-savings aspects of programmable automation is misleading: It plays on historic tensions between labor and management in this country, and it ignores the role of management, product design, and other cost factors in determining a company's ability to compete. There is a risk that, by emphasizing the one-for-one substitution of machines for people, companies will use PA inefficiently; they may ignore critical differences between what people and machines can do best, and they may ignore less tangible but effective options for improving human resource management or responsiveness to customer needs.**

PA will help many companies to produce better and cheaper. But whether the policy goal is to improve industrial competitiveness, maximize employment, or both, OTA'S research reveals a need for comprehensive rethinking of manufacturing processes and competitive strategies. With surprising consistency, automation experts consulted by OTA cited organizational factors, rather than technical ones, as the principal problems surrounding the use of PA. Thus, in several cases, PA feasibility studies have led to improvements in product design and production processes without the adoption of PA equipment. While new technology-i. e., new ways to combine equipment, personnel, and materials-can help manufacturing companies, experiences in the United States and abroad reveal that the success or failure of PA depends more on the management characteristics of the organizations that use it than on the particular choice of equipment and systems.

The technological, social, and economic concerns surrounding the spread of programmable automation are interconnected. Labor-saving technology does not necessarily cause unemployment: employment depends on what and how much consumers will buy, as well as how management decides to make those goods. Technology does not of itself raise or lower the skill levels required of employees: skill requirements depend on how management defines jobs and allocates work to suit an existing or preferred work force. Machines do not necessarily improve or degrade the work environment: equipment designers and managers make choices that determine how machines and people interact.

Programmable automation can improve the work environment, raise productivity, and create or preserve at least some jobs if it is developed and applied with those goals in mind. Because the markets for PA are still young and the use of PA is still relatively limited, the near-term social and economic effects of PA will not be cataclysmic. There is time for managers, employees, educators, and government to gain a

*other reasons include such factors as differences in materials and energy costs, differences in capital markets, the exchange rate, and changes in market size.

**This capital spending bias was brought out by a recent survey of industrial engineers. (Institute of Industrial Engineers, "productivity Today: An Inside Report," 1983.) As one reporter noted, "It seems clear that while more companies could benefit from trying to better use their employees, the role of capital spending-traditionally the 'quick fix' for improved industrial performance-will remain a major component of corporate strategy." Philip Moeller, "Firms Try To Boost Output," *The (Baltimore) Sun,* Oct. 19, 1983.

better understanding of PA and to plan to address the effects of automation on the workplace. Such advance planning will be necessary in order for the country to capture the potential benefits of PA and avoid excessive social and economic costs. Specific areas where long-range planning would be beneficial include analysis of changing skill requirements, improvements on the pairings of people with machines, and the roles and requirements for various educational institutions. Also important is the business climate for PA vendors and users.

# Study Approach, Organization, and Methodology

## Approach

To appreciate what programmable automation bodes for the U.S. economy, it is necessary to understand its key features, including its limitations and side effects as well as its expected benefits. This report examines those features largely from the perspective of the individual firm that may adopt PA. It focuses on the use of PA among discrete-product manufacturers, * particularly those in such metalworking industries as transportation equipment and electrical and nonelectrical machinery. These industries have been and will through this century continue to be leading users of PA. While many of the conclusions reached about the application of PA in metalworking industries may hold for other industries, generalizing about long-term effects of PA across industries-even among metalworking industries—is risky.

Where uncertainties exist, they are identified. Often, those uncertainties surround estimates of the amounts of change that are likely to arise from the spread of PA. The reliability of inferences about quantitative effects on industries, regions, and the national economy is limited because good data on economic and social aspects of PA do not exist. In particular, there is a scarcity of good data describing shifts in skill requirements, types of jobs, materials requirements, or the structure and competitive conduct of industries producing and using programmable automation. Consequently, it is too early to make precise, quantitative forecasts. Moreover, because technology, industry, and job characteristics are changing continually, descriptions of conditions at any one point will not necessarily hold up over time. This report therefore stresses the identification of the nature and direction of likely changes rather than their magnitudes.

This report examines a wide range of potential changes in the development and use of human resources that may accompany the spread of PA. Some will shape industry employment prospects, others will affect the work environment. Indeed, potential changes in the work environment will ultimately affect more people than changes in industry employment levels. While developments in employment and in the work environment may motivate new education and training activities, education and training in turn may shape the development, use, and employment effects of PA. In describing the ramifications of programmable automation for human resources, this report addresses the potential for nontechnological factors, from management style to industrial structure, to reinforce or conflict with the influences of PA itself.

The international context for PA development and use is highlighted throughout the report. While data on activities and programs abroad are limited and uneven in quality, each chapter relates phenomena in the United States to those abroad to the extent feasible. Actions in many countries will affect the level of technological development, the strength of the United States' claim to technological lead-

*Prducers of discrite products made in lots raging from one to mass-production quantity, such as industrial machines and automobiles, as opposed to continuous-process manufacturers, such as producers of chemicals and steel.

ership, and the ability of producers and users of PA to compete in domestic and foreign markets.

## Organization and Methodology

Following the executive summary and introduction, the prospects for programmable auto mation are examined in this report from several perspectives. Those perspectives are brought out through seven analytical and descriptive chapters. A final chapter presents congressional policy options. Each chapter draws on other chapters in the report, but is otherwise self-contained.

Chapter 3 addresses the questions, “What is programmable automation?” and “How might it be used?” It defines PA technologies-including computer-aided design, robots and other forms of computer-aided manufacturing, and related computer-based management systems—and describes their development trends. This chapter stresses the fact that PA is much bigger than robotics, which receives most of the attention, and it evaluates the potential for the integration of PA equipment into highly automated systems.

Chapters *4, 5,* and 6 address the question, “What are the implications of its use?” Chapter 4 examines the prospects for employment change, including the ways in which PA may influence job design and the number and mix of jobs among firms and industries. It also highlights conflicting influences on employment by occupation and industry. Chapter 5 explores the implications of the use of PA for the workplace. The chapter shows how technological features combine with management attitudes and actions to shape the work environment in manufacturing firms. Chapter 6 illuminates emerging needs for education, training, and retraining and discusses current efforts by industry, labor, and the academic community to meet those needs. It also discusses the relationship between PA-related skills development and broader educational preparation.

Chapter *7* addresses the questions, “Who produces PA equipment?” and “What is the status of producer industries?” It describes the structure and competitive conduct of industries supplying programmable automation goods and services. The chapter also characterizes the emerging role of these industries in the U.S. and world economies.

Chapters 8 and 9 provide background on the players involved and on existing directions in U.S. and foreign technology policy. Chapter 8 describes the roles of public and private institutions conducting PA research and development. Chapter 9 enumerates the efforts of governments in other countries to stimulate the production and use of programmable automation. These two chapters lead into chapter 10, which provides alternatives for congressional action.

The findings and insights of this report were developed from many sources of information. Technical literature and conference sessions provided background materials, but more direct development of information constituted the bulk of the research. Over the course of the study, OTA held workshops that brought together experts in the areas of employment change and industrial relations, programmable automation industries, and programmable automation technologies. OTA also conducted a survey of education, training, and retraining activities and opinions among producers and users of PA and among educators. In addition, 18 case studies were carried out. Fourteen described approaches to education, training, or retraining; four described some of the effects of PA on the work environment. Throughout the study, OTA staff visited facilities and consulted with a wide range of experts.

# Congressional Interest and Policy

The computerized manufacturing automation study was requested by the Joint Economic Committee, the Senate Committee on Labor and Human Resources, the Senate Committee on Commerce, Science, and Transportation, and the Labor Standards Subcommittee of the House Committee on Education and Labor. Other committees, including the House Committee on Science and Technology and the House Committee on Small Business, have also expressed interest in this study. Table 4 lists several relevant congressional hearings held during the development and conduct of this assessment.

**Table 4.—Representative Recent Congressional Hearings Relevant to Programmable Automation**

**Robotics**
June 2 and 23, 1982, 97th Cong., 2d sess.
Hearings before the Subcommittee on Investigations and Oversight to examine the status and potential applications of robotics technology R&D.

New **Technology in the American Workplace**
June 23, 1982, 97th Cong., 2d sess.
Hearing before the Subcommittee on Labor Standards to examine the impact of automation on employment and working conditions.

**Hearings on Mathematics and Science Education**
Sept. 28-30, 1982, 97th Cong., 2d sess.; and Jan. 26-28 and 31, 1983, 98th Cong., 1st sess.
Hearings before the Subcommittee on Elementary, Secondary, and Vocational Education and the Subcommittee on Postsecondary Education to consider several bills to improve mathematics and science education at the elementary and secondary level.

**Oversight of Trade Adjustment Assistance Programs and Authorization of Appropriations for U.S. Trade Representative, International Trade Commission, and Customs Service**
Mar. 17, 1983, 98th Cong., 1st sess.
Hearings before the Subcommittee on International Trade to consider the impacts of foreign trade and the fiscal year 1984 activities of concerned Federal agencies.

Impact of Robotics on Employment
Mar. 18, 1983, 98th Cong., 1st sess.
Hearing before the Subcommittee on Economic Goals and Intergovernmental Policy to examine the impact of automation, including robotics, on U.S. employment.

**Biological Clocks and Shift Work Scheduling**
Mar. 23 and 24, 1983, 98th Cong., 1st sess.
Hearings before the Subcommittee on Investigations and Oversight to examine research on human biological rhythms, such as the sleep-wake cycle, and their effect on job performance of shift workers.

Job Forecasting
Apr. 6 and 7, 1983, 98th Cong., 1st sess.
Hearings before the Subcommittee on Investigations and Oversight to examine implications of technology change for employment forecasting.

**The Impact of Robots and Computers on the Workforce in the 1980's**
May **17, 1983, 98th** Cong., 1st sess.
Hearing before the Subcommittee on General Oversight and the Economy on employment forecasting and technological change,

Administration Proposal for Block Grant for Vocational and Adult Education
May 19, 1983, 98th Cong,, 1st sess.
Hearings before the Subcommittee on Elementary, Secondary, and Vocational Education regarding the formulation and administration of Federal education grants to States.

Technology and Employment
June 7-10, 14-16, and 23, 1983, 98th Cong. lst sess.
Joint hearings before the Subcommittee on Science, Research, and Technology and the Task Force on Education and Employment regarding the range of effects of new technology on labor.

Industrial **Policy, Economic Growth and the Competitiveness of U.S. Industry**
June 24, 29, and 30; and July 13, 14, and 20, 1983, 98th Cong., 1st sess.
Hearings to examine issues and recommendations relating to a national industrial policy to facilitate industry capital formation i n order to promote and sustain economic growth.

**Joint Hearing on Plant Closing**
July 8, 1983, 98th Cong., 1st sess.
Joint hearing before the Subcommittee on Employment Opportunities and the Subcommittee on Labor-Management Relations of the Committee on Education and Labor regarding a bill to set conditions on plant closings.

Industrial Policy: the Retraining Needs of the Nation's Long-term, Structurally Unemployed Workers
Sept. 16, 23, 26, and Oct. 26, 1983, 98th Cong., 1st sess.
Hearings before the Joint Economic Committee on national retraining needs associated with structural change in the economy.

SOURCE Office of Technology Assessment

The extensive congressional interest in the study reflects the fact that programmable automation has numerous implications for policy. Recent policy discussions have tended to focus on either labor issues or international competitiveness. Indeed, concern for labor issues was a strong theme in the requests for the study.

This report addresses policy concerns in the areas of work environment, employment, education and training, and the development and use of programmable automation. Moreover, the policy discussion in chapter 10 emphasizes the interconnections between impacts and policies in all of those areas. It provides alternatives for congressional action that address those areas together as well as individually.